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AN INDUSTRIAL DYNAMICS STUDY
OF SELECTED FACTORS
AFFECTING COMPANY GROWTH

A THESIS

Presented to

The Faculty of the Graduate Division

by

Philip Edward Hicks

In Partial Fulfillment

of the Requirements for the Degree

Doctor of Philosophy

in the School of Industrial Engineering

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AN INDUSTRIAL DYNAMICS STUDY

OF SELECTED FACTORS

AFFECTING COMPANY GROWTH

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Chairman

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TABLE OF CONTENTS

TABLE OF CONTENTS (Continued)

LIST OF TABLES

LIST OF ILLUSTRATIONS

LIST OF ILLUSTRATIONS (Continued)

CHAPTER I

INTRODUCTION

The Nature of the Problem

A primary objective of most firms is some form of long-term profit or shareholder's equity maximization, consistent with other goals of the firm. Consequently, profit and net worth growth over a period of years represent variables of considerable interest to most managements. These two measures of growth depend on the structure of a particular organization, on the one hand, and specific company policy alternatives, on the other hand.

The quantitative description of the structure of a company, which is at the microeconomic level of analysis, may easily require several hundred variables. Similarly, the quantitative study of the effects of company growth requires the construction of dynamic models of great complexity. The practical solution of this type of problem in terms of classical mathematical techniques is virtually impossible.

The advent of computer simulation has made it possible to construct complex models of a given system structure and then experiment with the behavior of the simulated model through systematic changes in sensitive parameters. There are several approaches to computer simulation. One of them, known as "Industrial Dynamics" and developed by J. W. Forrester (9), has been employed in attacking large-scale simulation problems concerned with the dynamic behavior of economic and industrial systems. The DYNAMO (26) simulation language, created for programming industrial dynamics problems, provides an efficient computer programming means of specifying complex system relationships.

The purpose of this dissertation was to: (1) develop detailed computer simulation models of company growth in terms of DYNAMO special-purpose language and (2) evaluate the relative effects of employing alternative policies on selected company growth variables.

Prior Research

The field of mathematical economics, commonly referred to as econometrics, has a rich history of attempts to analyze economic systems or components of an economic system. R. G. D. Allen's (1) text, Mathematical Economics, summarizes past attempts to analyze economic systems by use of classical mathematics. Models developed by economists such as Harrod (11), Domar (6), Phillips (25), Hicks (12), Samuelson (27) and Kalecki (15) represent attempts to describe dynamic economic behavior with a limited number of variables.

A review of these models, however, reveals serious practical limitations of classical mathematical methods for the analysis of large-scale dynamic systems. When compared with the computer simulation approach to model building, classical mathematical methods suffer from the following limitations: (1) the number of variables must be relatively small, (2) the effects of delays between variables are not considered, and (3) the relationships between variables are assumed to be continuous functions. These difficulties are easily overcome in the computer simulation approach. The number of variables may be as large as several hundred, the provision for delays adds to the realism of the models, and discontinuous relationships can be handled easily by means of table functions.

Many recent attempts to analyze large-scale dynamic economic systems have employed computer simulation. The econometric model of the United States economy developed by Duesenberry, Fromm, Kle n and Kuh (8) is a representative example of such analysis at the macroeconomic level of aggregation. A number of simulation models concerned with description of particular industries also have been developed. Examples of these models are the shoe, leather and hide industries study of Cohen (4), the lumber industry study of Balderston and Hoggatt (2), the fuel manufacturing industry study of Hurford (14), and the copper and aluminum industries study of Schlager (29). Economic simulation models also have been developed which are sufficiently detailed as to consider individual consumers as basic components of the economic system. The simulation model of Orcutt, Greenberger, Korbel and Rivlin (23) is representative of models at this level of detail. Models concerned with detailed description of a firm as a component of the overall economic system have been developed by Bonini (3), Tonge (30), Hoggatt (13), Nord (22), Kinsley (16) and Packer (24), and are representative of economic models at the microeconomic level of economic system analysis.

Analog computers have been used in the past for simulating both economic and engineering models. Because the flow diagram of an analog model contains elements which represent terms in the classical mathematical model, the analog model flow diagram assists visualization of the mathematical analog of the physical system. However, other characteristics of analog computers, such as scaling problems, model size limitations, and noise level effects on accuracy, limit their capability relative to large-scale system analysis.

When analog formulation of a problem is desirable it is no longer necessary to perform the simulation on an analog computer. A number of digital analog simulator programs have been developed for use with digital computers. These programs allow formulation of problems as analog models, while permitting computation by digital means. Linebarger and Brennan (18) state that the first published digital analog simulator program was presented by R. G. Selfridge in 1955. Since that time, a considerable number of digital analog simulator programs have been developed. Linebarger and Brennan (18), in June, 1965, provided a detailed comparison of 27 digital analog simulator programs that had been developed as of that date.

Recent versions of digital analog simulator programs contain features which eliminate some of the prior objections to the use of analog computers. Program blocks can be stored on tape, parameter changes can be easily made, automatic scaling is now possible, and variable integration rate capability is available according to predefined error criteria. Therefore, the analog-formulated problem need no longer be solved on an analog computer.

In 1961, Forrester (9) presented a simulation method which he had developed and named "Industrial Dynamics." This simulation method considers any or all of six basic flows: namely, information, labor, equipment, orders, material and money. The simulation computation is in the form of linear difference equations. The model equations are of three main types: level, rate and auxiliary. The level equations algebraically sum inflows and outflows at points of interest in the six or less basic flows. The rate equations specify the rate of inflow to or outflow from each level, and the auxiliary equations are mathematical representations of the decision processes employed in the real-world system. The auxiliary equations serve as inputs to the rate equations, and therefore, affect the flow rates.

In 1963, Pugh (26) wrote a manual entitled DYNAMO User's Manual which describes a digital computer simulation language specifically developed for programming industrial dynamics models. Pugh states that DYNAMO consists of approximately 10,000 instructions written in machine language and that its development required six man-years of effort. He also states that DYNAMO can handle models containing as many as 1,400 equations, which provides an indication of the model size capability.

Although the DYNAMO simulation language was developed concurrently with industrial dynamics, its rather general formulation makes it a useful tool for analysis of problems somewhat outside the typical industrial dynamics problem area, such as the problem considered in this thesis. Industrial dynamics studies have been concerned mainly with the transient effects of system behavior. This author's research, however, involves the evaluation of relatively stable growth under varying policy conditions over a period of years.

A number of digital computer simulation languages could have been used for analysis of the problem under consideration. However, the DYNAMO simulation language was believed to possess the greatest capability for handling this problem. Company growth typically involves a continuous accumulation of resources as a result of a continuous feedback type of interplay between mutually dependent system variables. The following quotation from Krasnow and Merikallio (17) is believed to support the choice of DYNAMO for company growth simulation relative to the five simulation languages compared by these writers:

> In summary, CPSS might be said to provide a specialized realization of the more general concepts available in SIMSCRIPT and CSL. This specialization restricts its range of application, at the same time making it possible to bring greater power to bear on problems within this range. SIMPAC, with a similarly specialized outlook, provides a programming framework for utilizing more general concepts. DYNAMO, with a significantly different world view, is directed at a different class of application. It does not possess the descriptive capabilities of the other languages but nevertheless does have an extensive range of application for models of continuous information feedback systems (17, p. 256).

The works of Cyert and March (5), as well as March and Simon (20), offer appealing arguments for including a number of behavioral variables in economic models at the level of the firm. They have qualitatively considered such factors as satisficing attitudes, risk avoidance attitudes, search behavior, various personal motives, organizational slack (i.e., inefficient resource use), and sub-unit goals. Although present studies containing such factors typically lack a quantitative means of measuring their net system effects on the firm, the significance of their probable effects is difficult to deny intuitively.

In 1962, Bonini (3) developed a computer simulation model of "information and decision systems in the firm." His model incorporated many of the behavioral factors proposed by Cyert and March, and included both marketing and production functions. The simulation included consideration of such factors as organizational slack and profit aspiration levels. He developed, for example, an "index of pressure" scale for each functional manager to simulate the effects of managerial pressure applied in an attempt to secure satisficing profits. Typical of policy assumptions made in the model was an assumption that a poor immediate past record spurs company management to more actively pursue cost reduction goals.

Much of the development of Bonini's model is intuitively appealing; however, the behavioral variables considered often possess complex relationships for which little quantitative information exists to assist in constructing a quantitative model formulation. Therefore, although behavioral variables may exert a substantial effect on real world systems, the models developed in this thesis were limited, as much as possible, to those system variables which are not functionally dependent upon or sensitive to human behavior.

A number of industrial dynamics studies have been completed at the Massachusetts Institute of Technology in the last six years. The first company growth model was developed by Kinsley (16) in 1962. He developed a rather general model of both firm and market behavior which included both pricing policy and a competitive reactions formulation. The system included general consideration of production, sales, research and development, and financial functions. The study exposed the potential of industrial dynamics as a method of company growth analysis.

In 1963, Nord (22) developed a company growth model to study the effects of new product introduction on company growth. The model was developed to consider both market and firm effects. Revised policies were formulated and simulated in an attempt to improve the production acquisition policies of the firm. The basic model developed by Nord contained approximately 40 variables.

In 1964, Packer (24) developed an industrial dynamics simulation model to investigate the effect of various resource acquisition policies on company growth. The model included flows for labor, production capacity, orders, material and information, and contained approximately 60 variables. The main hypothesis tested by the Packer model was that company growth is significantly restricted by internal resource-acquisition policies. Simulation results for assumed initial and revised resource-acquisition policies for the models developed indicated that the hypothesis was true.

The Packer model was developed specifically for investigating the transient effects on company growth of professional labor, factory labor, and equipment acquisition policies. Therefore, labor acquisition and training, and equipment acquisition, were considered in detail to determine their transient effects on growth. Due to the limitation of interest in the Packer study to labor and equipment acquisition policies, financial factors were given secondary consideration as a restraint on growth and assumed to be solely an effect of other growth variables. This de-emphasis of financial restraints on growth is apparent from the following quotation from the Packer study:

> Only those aspects of the firm's operations discussed in the preceding hypothesis are considered in the study. Readers will, perhaps, regard the omission of financial factors as striking in a growth study. While we do not pretend that cash flows, capital requirements, and profits are never crucial to growth, we do feel that often financial problems are but symptoms of difficulties whose basic causes lie elsewhere, such as in the set of interactions considered here (24, p.14).

The most recent published work in the area of company model simulation, more specifically concerned with short-term productivity than long-term growth, is that of Kenneth J. Schlager (28), at the Center for Productivity Motivation, School of Commerce, University of Wisconsin. This research produced company simulation models for two manufacturing firms in the Milwaukee area. The first model provided a general formulation of the overall operation of the Badger Meter Manufacturing Company. The second model was a more microscopic simulation of the job order scheduling function within another manufacturing firm.

A conclusion from the research relative to the appropriate level of detail of system formulation is indicated in the following quotation:

> This second model provided a suitable complement to the more general Badger Meter Model. Experience gained in both companies would seem to indicate that a full-scale application of the systems concept in a company would require a hierarchy of simulation models since no one model can provide both the depth and breadth needed for all of a company's operations (28, p. 5).

The limitations in obtaining both breadth and depth in a single model will be discussed later in this report relative to the two models developed in this thesis.

A second conclusion from Schlager's study concerned the need for improved information-decision systems. The following quotation suggests the basic characteristics of such a system:

> . . . by a second approach which involves a redesign of the information-decision system used within the company. In this approach, the new decision rules are made operational by providing an "on-line" information system that is structured around the needs of the new decision-pattern (28, p. 47).

This point also will be discussed later in this report since a similar need for structuring the information system relative to the revised policy needs was encountered in the analysis of the problem under consideration.

The Packer model (24), up to the time of this writing, represents the most extensive analysis in the area of industrial dynamics company growth simulation. The Packer model has certain basic limitations, however, which creates a need for further research. Two main limitations are the following: financial policy is not considered as a possible major restraint on company growth; and the model contains only 60 variables, which limits consideration of certain alternative policies which require a detailed formulation in the functional area involved.

The Research Objectives

The main objective of the research was to develop detailed company growth simulation models and to test the relative effect on company growth of employing specific alternative policies. Initial development effort was to be expended in developing a detailed model for a hypothetical manufacturing company, and a second model was to be developed to validate growth model simulation results by comparing simulated growth with an existing firm's past growth.

The first model, referred to as Model A, is the hypothetical company growth model. The model is especially detailed with respect to characteristics of discrete units of process capability. Formulations for factory and professional labor in both models parallel formulations employed in the Packer model because the depth and underlying basis of formulation were ideally suited to these models.

The second model, referred to as Model B, is the actual company model. In this study, the company is fictitiously referred to as the ABC Company, because the management of the actual company from which the information was obtained preferred that its corporate name not be identified because of the proprietary nature of the financial information provided. For that reason, all equipment and products referred to in this thesis relative to the second model possess code names to prevent actual company identification. The second model is less detailed than the first model because of inherent limitations in attempting to employ whatever actual company historical information was available to a previously unintended informational purpose.

CHAPTER II

THE HYPOTHETICAL COMPANY GROWTH MODEL

General Assumptions of the Model

The hypothetical company growth model, referred to as Model A, is intended to model the growth of a small manufacturing company. Because this research was particularly concerned with internal operational policies of the firm, the simulation formulation was developed in depth in those sectors of the model possessing primary growth variables. Since capital, labor and equipment acquisition policies were assumed to be the major determinants of growth, those sectors of the model were developed in greatest detail. Other sectors of the model were developed to the extent assumed appropriate in the light of their probable influence on growth variables.

Manufacturing typically involves a fixed sequence of major processing units for manufacture of a product; to reflect this condition, Model A was developed to represent a manufacturing facility employing three serial processes. Since each process within a manufacturing firm often employs some multiple of a fundamental unit of processing capability, in the form of one unit of equipment for that process, the simulation model was developed to consider discrete units of processing capability for each process.

This research was particularly concerned with the manner in which resources such as capital, labor and equipment are employed in the firm. The research was not intended, however, to consider the effects on company growth of restrictions on availability of these resources. Therefore, the model formulation was developed with the assumption that resources are available throughout the simulation period at constant prices.

A Description of the Company Growth Process

Model A consists of 11 sectors possessing major interconnections as indicated in Figure 1. The sectors represent major resource or decision activities of the firm. Combined they represent a company growth process for the hypothetical company. The following is a brief description of how the sectors and their major connecting relationships constitute a company growth process.

The company demand sector serves to generate a product demand for the firm. The formulation for company demand assumes a variable fraction of a constant total market demand as a function of the total delivery delay to the customer. As the overall processing capacity for the plant increases, permitting a reduction in the process delay for goods to the customer, the fraction of market demand captured by the company is increased, and vice versa.

The material flow sector, which includes three serial processes, is limited in its ability to grow by resource availability in the form of labor, equipment, or capital. Each resource must be obtained, however, within specified restrictions.

The material flow capacity can be labor restricted if the hiring policies within the factory labor sector are ineffective in providing an adequate supply of trained labor as required to man additional processing equipment. However, if excess labor is available, the profit capability of the operation is limited.

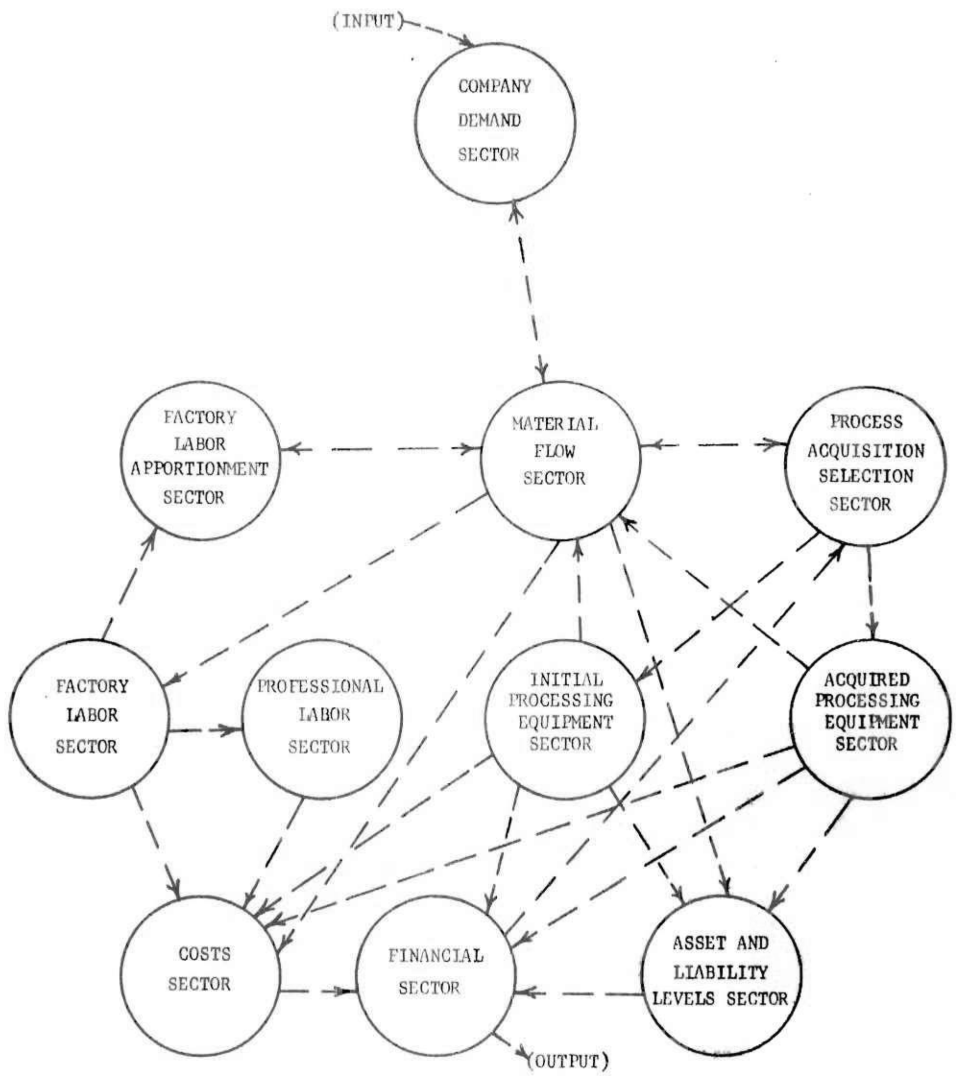


Figure 1. A Simplified Flow Diagram of Model A

In order to make effective use of available labor, the factory labor apportionment sector of the model allocates labor first to the limiting process, and then distributes the remaining labor to the two remaining processes in proportion to their respective processing needs. This formulation assumes, therefore, that the labor pool is sufficiently flexible to allow the limiting process to have the labor it needs to man existing equipment.

Since a three-series process is assumed, with each process growing independently, any one of the three processes can be the limiting process and must, therefore, be identified. The process acquisition selection sector serves to identify which of the three processes is limiting total output. When additional equipment is acquired, it is added to the limiting process.

At the beginning of the simulation period, a specified quantity of equipment at various stages of equipment life is specified for each process. Characteristics of the individual units of equipment, such as scrap rate, equipment expense, or depreciation, are a function of equipment type and life. Therefore, process capability and expense are a function of the age of equipment within each process.

Similar characteristics for acquired equipment are available within the formulation which become effective at such time during the simulation as an additional unit is purchased for a specific process. Equipment acquisition to a process is dependent upon: 1) identification of the limiting process, 2) availability of cash for equipment investment, and 3) an increasing company demand.

The costs sector and the asset and liability levels sector serve as inputs to the financial sector, which maintains a continuous accounting of the financial condition of the company. Defined financial policy of the firm can limit growth of the company by restricting the availability of capital for purchase of additional equipment. Funds for purchase of additional equipment come from either accumulated profits or borrowing. Borrowing, of a specified increment of funds, is permitted only when: (1) insufficient cash exists for purchase of an additional equipment unit, (2) the average profit rate for the firm is above a defined minimum, and (3) the interest rate to the firm, a function of the debt-equity ratio, is below a defined maximum interest rate.

Within the above restrictions, the firm attempts to grow by increasing its process capability, and the extent of growth is a function of specified policies within each sector of the model.

Simulation Model Sectors

The following is both a description of the approach and assumptions relative to the development of each sector and a detailed description of the formulation for each sector. Appendix A is a listing of the Model A DYNAMO formulation for assumed existing policies, and Appendix B is a glossary for variables and constants defined in Model A.

Throughout the formulation, a number of constants employed in the formulation are assigned specified values. Equation A1 represents such an assignment as follows:

```
C       MD=1500                                              (A1)
```

Equation A1 assigns a value of 1500 to the market demand (MD), which will remain constant throughout the simulation. Since the assignment of specific values to all other constants employed in the formulation is accomplished in a similar manner, constant equations will not be considered further in the following description unless the value employed requires explanation. If the value assigned is not explained in this section, it is assumed to represent a logical value assignment for the hypothetical company model.

In the description to follow, each equation employed in the model is represented by one line from the computer program. Each line consists of three elements, which are, from left to right: (1) the equation form and type designation, (2) the time subscripted equation, and (3) the equation identification number. Equation forms and types are explained in detail in the DYNAMO User's Manual (26), as well as appropriate time subscripts for equations employed. Briefly stated, the form and type designation specifies an appropriate number and arrangement of variables, appropriately time subscripted. If not, an error message results from system consideration of the formulation. Therefore, the equation form and type designation and time subscripts serve a diagnostic role in assisting system identification of programming errors.

Company Demand Sector

The company demand sector was formulated to provide the overall model with a sales input. The demand sector represents the total effect of all marketing efforts as well as other efforts of the firm within its external economic environment. This sector was developed with a minimum of detail since marketing policies of the firm and external economic variables were considered to be beyond the scope of this research. Figure 2 is a flow diagram of the company demand sector of Model A.

The company demand formulation was developed with the assumption that a single product manufactured by the firm sells at a fixed price throughout the simulation period and that the only variable having a direct effect on the percentage of the market demand that the firm retains is delivery delay. Therefore, "fraction of the market" is a table value as a function of delivery delay. Company demand is a variable fraction of a constant total market demand.

Equation A2 defines the total delivery delay (DD) to be the sum of the order backlog delivery delay (DD1), delivery delay for material flow through each of the three process (DD2, DD3 and DD4), delivery delay in final storage (DD5), and a two-week delay in shipment to the customer.

10A DD.K=DD1.K+DD2.K+DD3.K=KK4.K+DD5.K+2 (A2)

Equation A3 defines the order backlog delivery delay (DD1) to be equal to the order backlog quantity (OB) divided by the weekly average order output rate (AOOR).

20A DD1.K=OB.K/AOOR.K (A3)

Equation A4 defines the delivery delay in process one (DD2) to be equal to the material in process one (MIP1) divided by the average process one material leaving rate (AP1LR).

20A DD2.K=MIP1.K/AP1LR.K (A4)

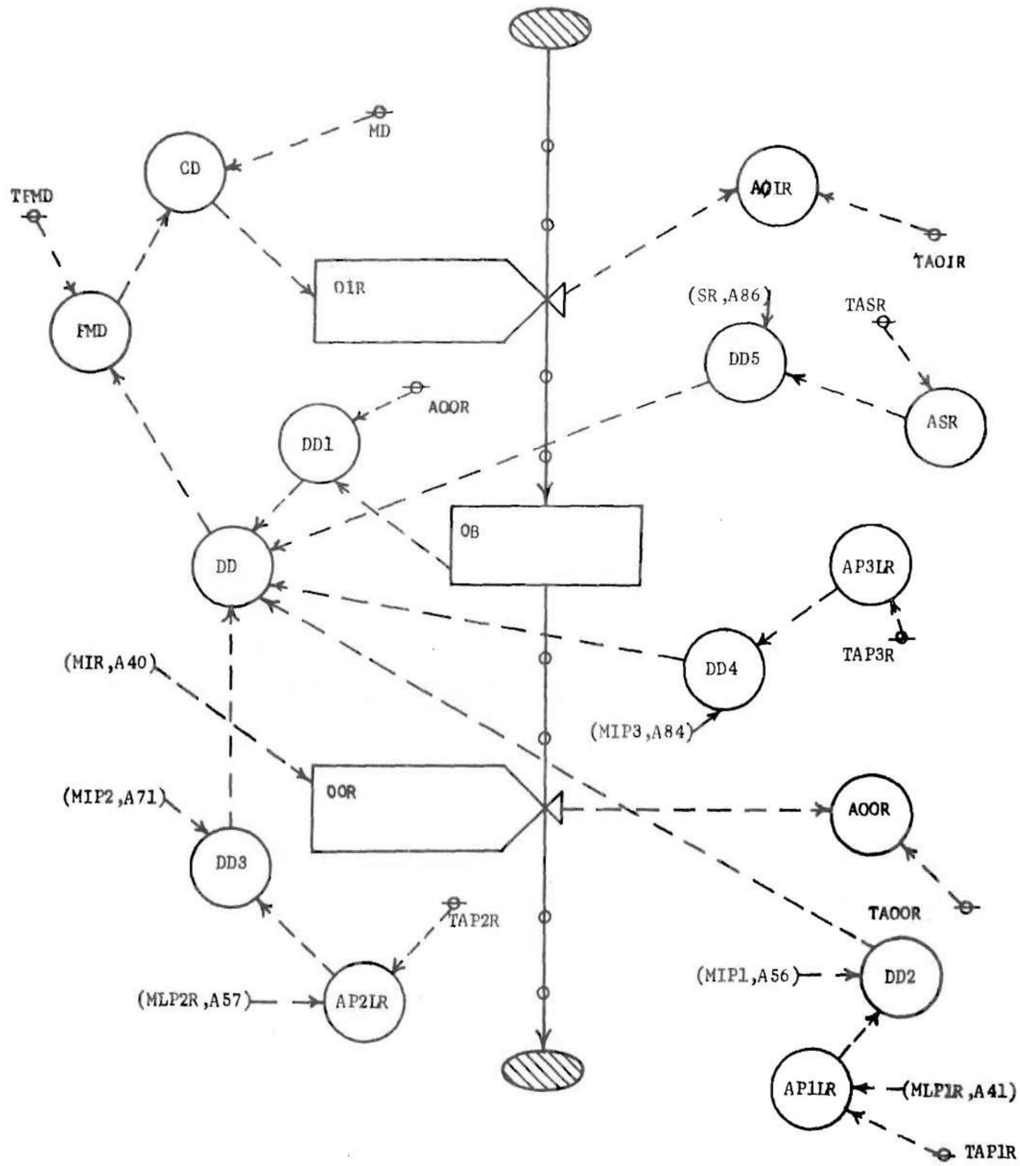


Figure 2. A Flow Diagram of the Company Demand Sector of Model A

Equation A5 defines the delivery delay in process two (DD3) to be equal to the material in process two (MIP2) divided by the average process two leaving rate (AP2LR).

20A DD3.K=MIP2.K/AP2LR.K (A5)

Equation A6 defines the delivery delay in process three (DD4) to be equal to the material in process three (MIP3) divided by the average process three leaving rate (AP3LR).

20A DD4.K=MIP3.K/AP3LR.K (A6)

Equation A7 defines the delivery delay in final storage (DD5) to be equal to the final product awaiting shipment (FPAS) divided by the average shipping rate (ASR).

20A DD.5K=FPAS.K/ASR.K (A7)

Equation A8 defines the fraction of market demand (FMD) to be a table function of delivery delay (DD), starting at zero weeks and ending with 50 weeks, in increments of five weeks. Equation A9 assigns table values to the fraction of market demand (FMD) corresponding to the above incremental values of the delivery delay (DD).

58A FMD.K=TABHL(TFMD,DD.K,0,50,5) (A8)

C TFMD*=2/.2/.15/.1/.075/.05/.05/.05/.05//05/0 (A9)

Figure 3 on the following page is a graph of the fraction of market demand (FMD) as a function of delivery delay (DD).

Equation A10 defines the company demand (CD) to be equal to the

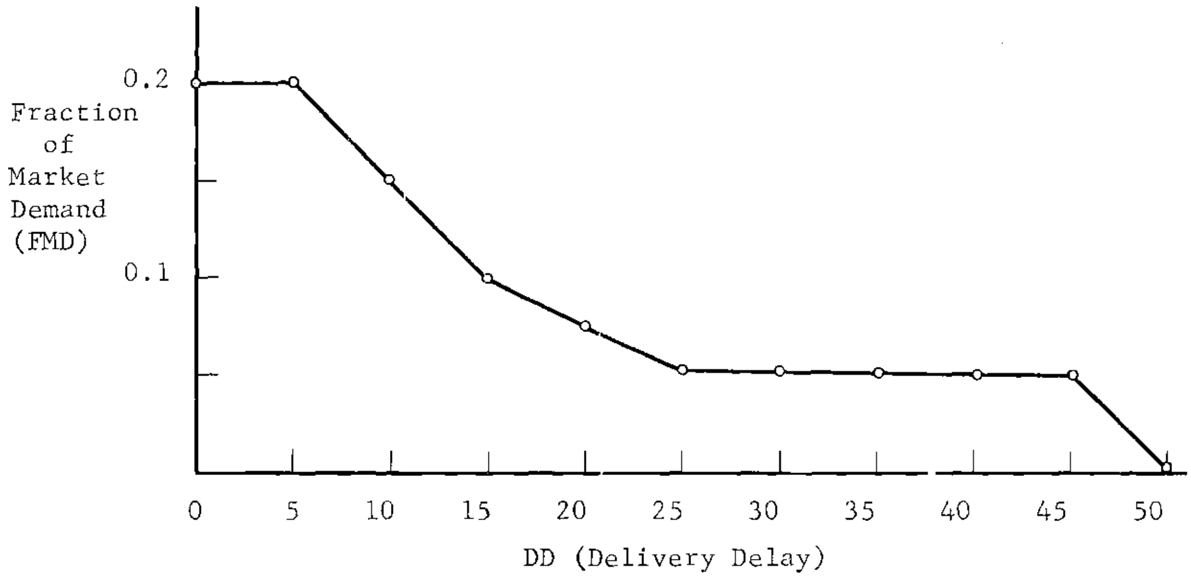


Figure 3. Fraction of Market Demand (FMD) versus Delivery Delay (DD).

product of the fraction of market demand (FMD) and the market demand (MD).

12A CD.K=(FMD.K)(MD) (A10)

Equation A11 defines the order input rate (OIR) to be equal to the company demand (CD).

6R OIR.KL=CD.K (A11)

Equation A12 defines the order backlog (OB) at time K to be equal to the order backlog at time J plus the difference between the order in put rate (OIR) and the order output rate (OOR) during interval JK.

1L OB.K=OB.J+(DT)(OIR.JK-OOR.JK) (A12)

Equation A13 defines the order output rate (OOR) from the order backlog, to be equal to the material input rate (MIR). It was assumed that the flow of materials into process one determines the rate at which the order backlog can be reduced. Material input rate (MIR) is defined in the material flow sector of this model.

6R OOR.KL=MIR.JK (A13)

Equation A14 defines the average order input rate (AOIR) at time K to be equal to the average order input rate at time J plus the difference between the order input rate (OIR) and the average order input rate (AOIR) for interval JK, divided by the time to average the order input rate constant (TAOIR).

3L AOIR.K=AOIR.J+(DT)(1/TAOIR)(OIR.JK-AOIR.J) (A14)

Equation A16 defines the average order output rate (AOOR) at time K to be equal to the average order output rate at time J plus the difference between the order output rate (OOR) and the average order output rate (AOOR) during interval JK, divided by the time to average the order output rate constant (TAOOR).

3L AOOR.K=AOOR.J+(DT)(1/TAOOR)(OOR.JK-AOOR.J) (A16)

Equation A18 defines the average process one leaving rate (AP1LR) at time K to be equal to the average process one leaving rate at time J plus the difference between the material leaving process one rate (MLP1R) and the average process one leaving rate (AP1LR) during interval JK, divided by the time to average the process one leaving rate constant (TAP1R).

3L AP1LR.K=AP1LR.J+(DT)(1/TAP1R)(MLP1R.J-AP1LR.J) (A18)

Equation A20 defines the average process two leaving rate (AP2LR) at time K to be equal to the average process two leaving rate at time J plus the difference between the material leaving process two rate (MLP2R) and the average process two leaving rate (AP2LR) during interval JK, divided by the time to average the process two leaving rate constant (TAP2R).

3L AP2LR.K=AP2LR.J+(DT)(1/TAP2R)(MLP2R.J-AP2LR.J) (A20)

Equation A22 defines the average process three leaving rate (AP3LR) at time K to be equal to the average process three leaving rate at time J plus the difference between the material leaving process three rate (MLP3R) and the average process three leaving rate (AP3LR) during interval JK, divided by the time to average the process three leaving rate constant (TAP3R).

3L AP3LR.K=AP3LR.J+(DT)(1/TAP3R)(MLP3R.J-AP3LR.J) (A22)

Equation A24 defines the average shipping rate (ASR) at time K to be equal to the average shipping rate at time J plus the difference between the shipping rate (SR) and the average shipping rate (ASR) during interval JK, divided by the time to average the shipping rate constant (TASR).

3L ASR.K=ASR.J+(DT)(1/TASR)(SR.JK-ASR.J) (A24)

<u>Material Flow Sector</u>

The material flow sector represents the flow of material in all stages of acquisition, production and disposition, and begins with the purchase of basic materials for material stock. It includes their issuance from stock, to and through the first, second and third processes and final storage, and ends with a delayed shipment from final storage. Material ordering was formulated in such a way that the material stock level is compared to a desired stock level, which is a multiple of the order input rate. Material is ordered in an effort to gradually bring the actual stock level up to the desired level in a defined number of weeks. The above is graphically portrayed in Figure 4, which is a flow diagram for the material flow sector of Model A.

Material input to processes one, two and three was formulated to consider a number of restrictions on material flow. A calculation of material processing capability is made for each process as a function of the number of equipment units available to each process. A total scrap rate also is developed for each process group of machines, and a desired material input is determined. Also included, however, were two other restrictions which may reduce the material input to a process. If the material in a specific process reaches a defined maximum limit, the input rate is restricted to a level which will match its present output rate. This restriction was included to represent process space limitations for the storage of in-process material. The second restriction of material input to a process below the desired level, determined in relation to the availability of equipment, is based on a calculation of available factory labor. If factory labor for processing equipment is insufficient relative to equipment demands for factory labor, process labor becomes the determinant of material flow through each process.

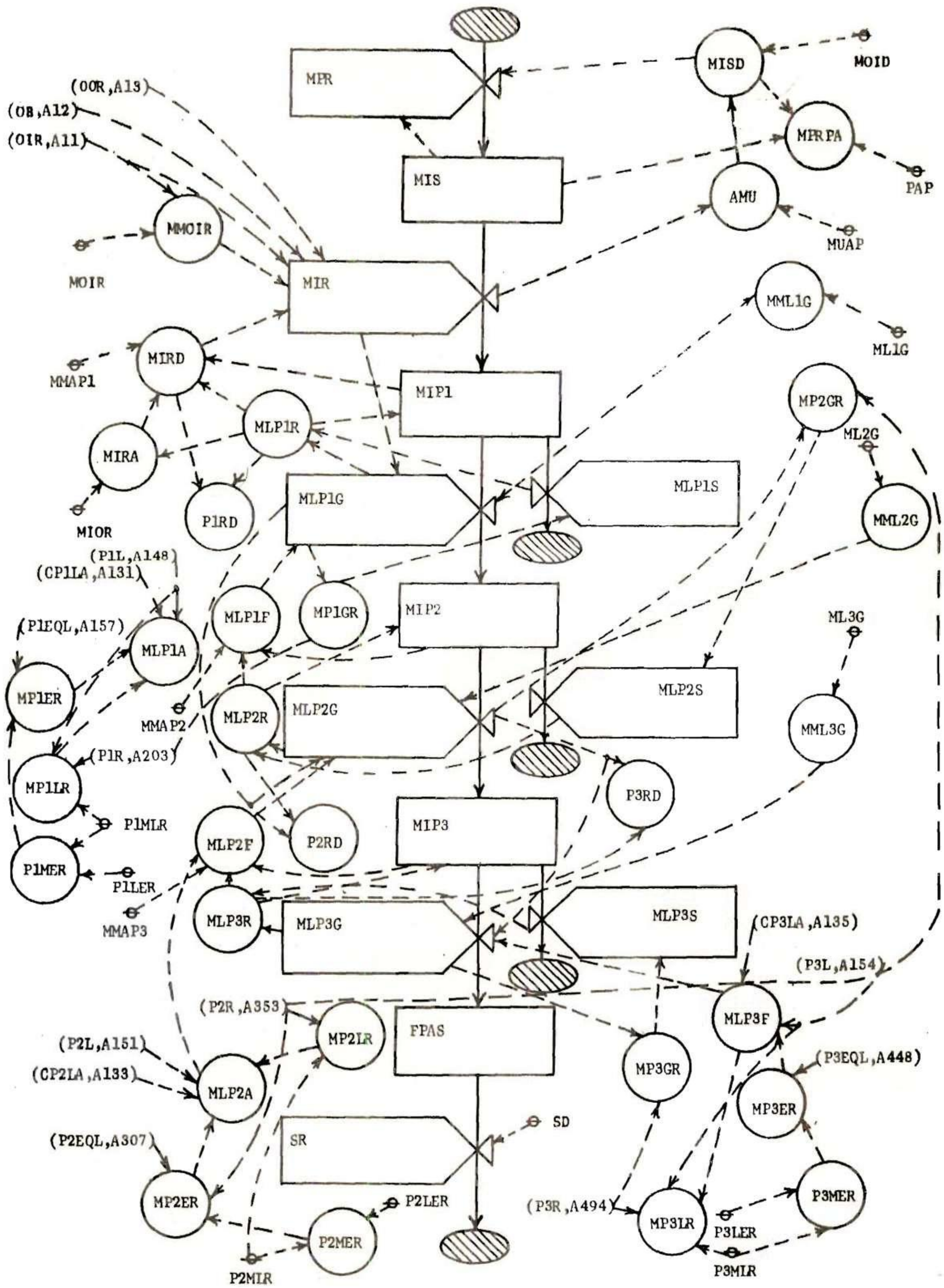


Figure 4. A Flow Diagram of the Material Flow Sector of Model A

Equation A26 defines the material in stock desired (MISD) to be equal to the product of four times the average material usage per week (AMU) and the number of months of material inventory desired (MOID).

13A MISD.K=(AMU.K)(MOID)(4) (A26)

Equation A28 defines the average material usage (AMU) at time K to be equal to the average material usage at time J plus the difference between the material input rate (MIR) and the average material usage (AMU) during interval JK, divided by the material usage averaging period constant (MUAP).

3L AMU.K=AMU.J+(DT)(1/MUAP)(MIR.JK-AMU.J) (A28)

Equation A30 defines the material purchase rate employing policy A (MPRPA) to be equal to the difference between the material in stock desired (MISD) and the material in stock (MIS), divided by the purchasing adjustment period constant (PAP).

21A MPRPA.K=(1/PAP)(MISD.K-MIS.K) (A30)

Equation A32 defines the material purchase rate (MPR) to be equal to the material purchase rate employing policy A (MPRPA) if the material in stock desired (MISD) is equal to or greater than the material in stock (MIS); otherwise, it is defined as equal to zero.

51R MPR.KL=CLIP(MPRPA.K,0,MISD.K,MIS.K) (A32)

Equation A33 defines the material in stock (MIS) at time K to be equal to the material in stock at time J plus the difference between the material purchase rate (MPR) and the material input rate (MIR) during interval JK.

1L MIS.K=MIS.J+(DT)(MPR.JK-MIR.JK) (A33)

Equation A34 defines the material input rate under policy A (MIRA) to be equal to the product of the material input to output ratio (MIOR) and the material leaving process one rate (MLP1R).

12A MIRA.K=(MIOR)(MLP1R.K) (A34)

Equation A36 defines the material input rate desired (MIRD) to be equal to the material leaving process one rate (MLP1R) if the material in process one (MIP1) is equal to or greater than the maximum material allowed in process one quantity (MMAP1); otherwise, it is defined as equal to the material input rate employing policy A (MIRA).

51A MIRD.K=CLIP(MLP1R.K,MIRA.K,MIP1.K,MMAP1) (A36)

Equation A38 defines the minimum multiple of the order input rate (MMOIR) to be equal to the product of the specified multiple of the order input rate (MOIR) and the order input rate (OIR).

12A MMOIR.K=(MOIR)(OIR.K) (A38)

Equation A40 defines the material input rate (MIR) to be equal to the material input rate desired (MIRD) if the order backlog (OB) is equal to or greater than the minimum multiple of the order input rate (MMOIR); otherwise, it is defined as equal to the order input rate (OIR).

51R MIR.KL=CLIP(MIRD.K,OIR.K,OB.K,MMOIR.K) (A40)

Equation A41 defines the material leaving process one rate (MLP1R) to be equal to the sum of the material leaving process one good rate (MLP1G) and the material leaving process one scrap rate (MLP1S).

7A MLP1R.K=MLP1G.JK+MLP1S.JK (A41)

Equation A42 defines the material leaving process one good rate (MLP1G) to be equal to the material leaving process one value F rate (MLP1F) if the material in process one (MIP1) is equal to or greater than the minimum multiple amount of good material leaving process one (MML1G); otherwise, it is defined as equal to the material input rate (MIR). This formulation limits the material output from process one to the material input rate if the material in process is below a minimal level. The formulation, therefore, insures non-negativity of the material in process value, and its rationale as a formulation is a condition observable in some manufacturing organizations (i.e., as the total volume of work available to a department decreases, the output of the department approaches the work input rate to the department).

51R MLP1G.KL=CLIP(MLP1F.K,MIR.K,MIP1.K,MML1G.K) (A42)

Equation A43 defines the minimum multiple amount of good material leaving process one (MML1G) to be equal to the product of the multiple of good material leaving process one (ML1G) and the amount of good material leaving process one (MLP1G).

12A MML1G.K=(ML1G)(MLP1G.K) (A43)

Equation A45 defines the process one material rate difference

(P1RD) to be equal to the difference between the material leaving process one rate (MLP1R) and the material input rate (MIR).

7A P1RD.K+MLP1R.K-MIR.JK (A45)

Equation A46 defines the material leaving process one policy F rate (MLP1F) to be equal to the material leaving process two rate (MLP2R) if the material in process two (MIP2) is equal to or greater than the maximum material allowed in process two (MMAP2); otherwise, it is defined as equal to the material leaving process one policy A rate (MLP1A). This formulation limits the output rate from process one, which is the input to process two, to the output rate of process two if material in process has reached the allowed upper limit for material storage. If material in process is below the upper limit, the process one leaving rate is set equal to MLP1A, which is either equipment or labor restricted.

51A MLP1F.K=CLIP(MLP2R.K,MLP1A.K,MIP2.K,MMAP2) (A46)

Equation A48 defines the material leaving process one policy A rate (MLP1A) to be equal to the material leaving process one when equipment restricted (MP1ER) if process one labor (P1L) is equal to or greater than the critical process one labor amount (CP1LA); otherwise, it is defined as equal to the material leaving process one when labor restricted rate (MP1LR).

51A MLP1A.K=CLIP(MP1ER.K,MP1LR.K,P1L.K,CP1LA.K) (A48)

Equation A49 defines the material leaving process one when equipment restricted (MP1ER) to be equal to the product of the process one equipment quantity level (P1EQL), the process one reliability (P1R), and the process one material to equipment ratio (P1MER).

13A MP1ER.K=(P1EQL.K)(P1R.K)(P1MER.K) (A49)

Equation A50 defines the process one material to equipment ratio (P1MER) to be equal to the product of the process one material to labor ratio (P1MLR) and the process one labor to equipment ratio (P1LER).

12A P1MER.K=(P1MLR)(P1LER) (A50)

Equation A53 defines the material leaving process one when labor restricted rate (MP1LR) to be equal to the product of the process one labor quantity (P1L), the process one material to labor ratio (P1MLR), and the process one reliability (P1R).

13A MP1LR.K=(P1L.K)(P1MLR)(P1R.K) (A53)

Equation A54 defines the total material leaving process one rate (MP1GR) to be equal to the good material leaving process one rate (MLP1G) divided by the process one reliability (P1R).

20A MP1GR.K=MLP1G.JK/P1R.K (A54)

Equation A55 defines the scrap material leaving process one rate (MLP1S) to be equal to the product of the total material leaving process one rate (MP1GR) and one minus the process one reliability (P1R).

18R MLP1S.KL=(MP1GR.K)(1-P1R.K) (A55)

Equation A56 defines the material in process one (MIP1) at time K to be equal to the material in process one at time J plus the difference between the material input rate (MIR) and the material leaving process one rate (MLP1R) during interval JK.

1L MIP1.K=MIP1.J+(DT)(MIR.JK-MLP1R.J) (A56)

Equations A57 to A84 inclusive are analogous formulations for processes two and three, as compared to the process one formulations.

Equation A85 defines final product awaiting shipment (FPAS) at time K to be equal to final product awaiting shipment at time J plus the difference between the good material leaving process three rate (MLP3G) and the shipping rate (SR) during interval JK.

1L FPAS.K=FPAS.J+(DT)(MLP3G.JK-SR.JK) (A85)

Equation A86 defines the shipping rate to be equal to the final product awaiting shipment (FPAS) divided by the shipping delay (SD).

20R SR.KL=FPAS.K/SD (A86)

Process Acquisition Selection Sector

This sector was developed to provide a means within the model formulation for selection of additional processing equipment in relation to the relative demands being placed on process groups of equipment for material processing capability. The formulation also considers the following two additional factors: (1) whether funds are available for additional equipment investment, and (2) whether the average input rate at the time of considering addition of a processing unit is in excess of the present processing capability. Figure 5 is a flow diagram for the process

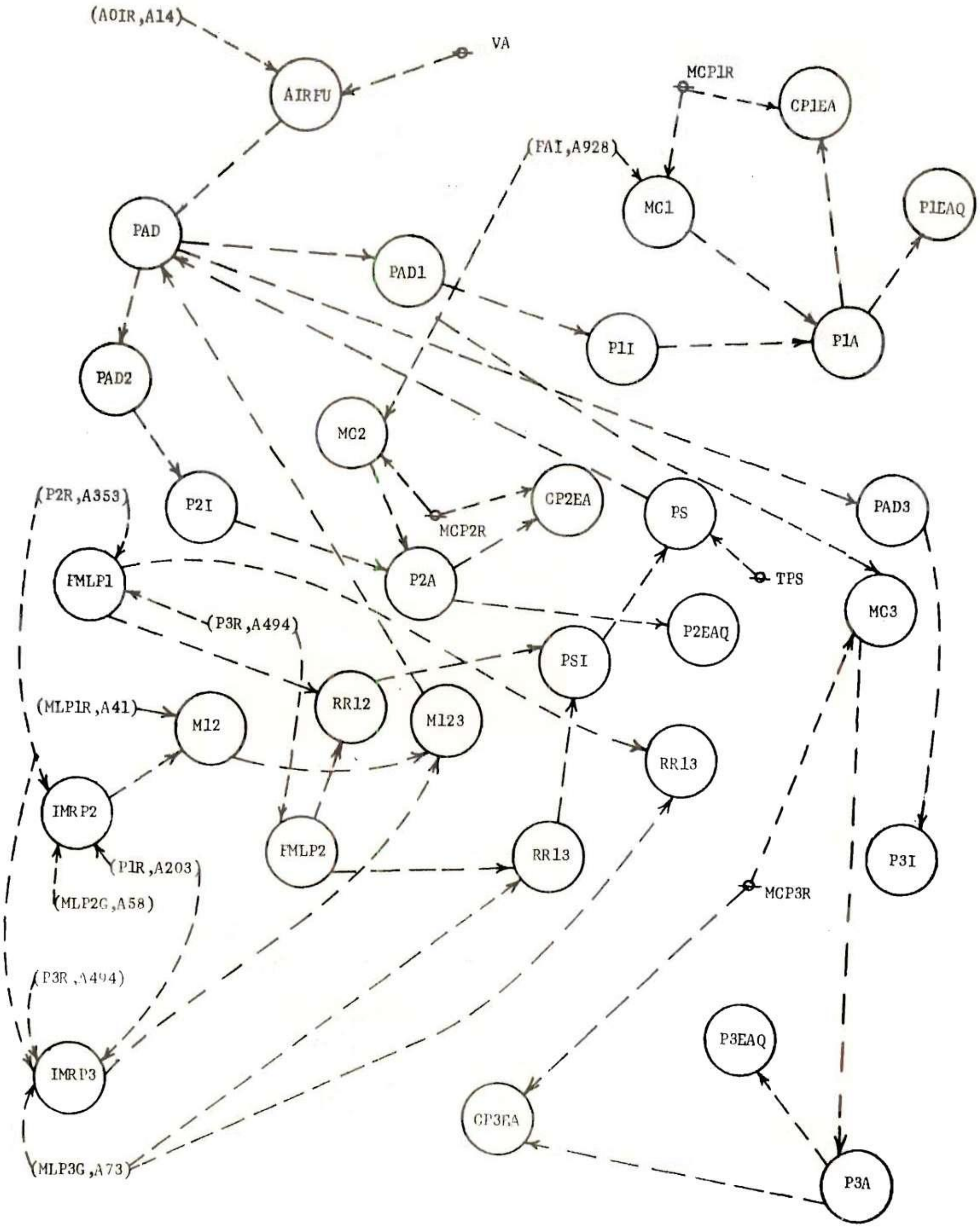


Figure 5. A Flow Diagram of the Process Acquisition

Selection Sector of Model A

acquisition selection sector of Model A.

The process acquisition selection formulation compares the relative processing capability of each process for the final product output through all three processes net of scrap losses at each process. The process with the minimum final product production capability is identified as the limiting process, and the next addition of a processing unit is made to the limiting process. The acquisition is made when sufficient investment funds are available and a check of the average order input rate indicates that the present processing capability is insufficient relative to the average company product demand.

Equation A88 defines the relative rate of process one compared to process two index value (RR12) to be equal to one if the final material leaving process two (FMLP2) is equal to or greater than the final material leaving process one (FMLP1); otherwise, it is defined as equal to zero.

51A RR12.K=CLIP(1,0,FMLP2.K,FMLP1.K) (A88)

Equation A89 defines the relative rate of process one as compared to process three index value (RR13) to be equal to five if the good material leaving process three rate (MLP3G) is equal to or greater than the final material leaving process one (FMLP1); otherwise, it is defined as equal to zero.

51A RR13.K=CLIP(5,0,MLP3G.K,FMLP1.K) (A89)

Equation A90 defines the final material leaving process one (FMLP1) to be equal to the product of the good material process one rate

(MLP1G), process two reliability (P2R), and process three reliability (P3R).

13A FMLP1.K=(MLP1G.JK)(P2R.K)(P3R.K) (A90)

Equation A91 defines final material leaving process two (FMLP2) to be equal to the product of good material leaving process two (MLP2G) and process three reliability (P3R).

12A FMLP2.K=(MLP2G.JK)(P3R.K) (A91)

Equation A92 defines the relative rate of process two compared to process three index value (RR23) to be equal to three if good material leaving process three rate (MLP3G) is equal to or greater than final material leaving process two (FMLP2); otherwise, it is defined as equal to zero.

51A RR23.K=CLIP(3,0,MLP3G.K,FMLP2.K) (A92)

Equation A93 defines the process selection index (PSI) to be equal to the sum of the three relative rate index values (i.e., RR12, RR13, and RR23).

8A PSI.K=RR12.K+RR23.K+RR13.K (A93)

Equation A94 defines the process selected (PS) to be a function of the tabled process selection index (PSI) values, starting with zero and increasing in increments of one to nine. Equation A95 assigns table values to the process selected (PS) corresponding to the above incremental values of the process selection index (PSI).

59A PS.K=TABLE(TPS,PSI.K,0,9,1) (A94)

C TPS*=3/3/0/2/0/0/1/0/2/1 (A95)

The above formulation assigns to the process selected (PS) the number of the process which is minimizing flow through the total process. For example, if process three is the minimizing process and process two has a final product capacity in excess of process one, values for RR12, RR13, RR23, PSI and consequently PS are respectively one, zero, zero, one and three.

Equation A96 defines the average input rate allowing for undercapacity (AIRFU) to be equal to the product of the average order input rate (AOIR) and one minus the undercapacity allowance (UA).

18A AIRFU.K=(AOIR.K)(1-UA) (A96)

Equation A98 defines the process acquisition desired index (PAD) to be equal to the process selected (PS) if the average input rate allowing for undercapacity (AIRFU) is equal to or greater than the minimum initial entering rate to the three processes (M123); otherwise, it is defined as equal to zero.

51A PAD.K=CLIP(PS.K,0,AIRFU.K,M123.K) (A98)

This formulation assigns PAD the value of PS if sufficient order input exists relative to present capacity such that after providing for some allowable undercapacity, the adjusted order input rate is in excess of the minimum process capacity. This formulation, therefore, provides the means for assuring that a sufficient input rate exists relative to the present processing capacity to justify acquisition of an additional processing unit.

Equation A99 defines the minimum initial entering rate to processes one and two (M12) to be equal to the minimum of the material leaving process one rate (MLP1R) and the initial material entering rate for process two (IMRP2). Material leaving process one (MLP1R), which includes good and scrap materials, equals the initial material entering process one.

54A M12.K=MIN(MLP1R.K,IMRP2.K) (A99)

Equation A100 defines the minimum initial entering rate to the three processes (M123) to be the minimum of the minimum initial entering rate to processes one and two (M12) and the initial material entering rate to process three (IMRP3).

54A M123.K=MIN(M12.K,IMRP3.K) (A100)

Equation A101 defines the initial material entering rate to process two (IMRP2) to be equal to the good material leaving process two rate (MLP2G) divided by the product of the process one reliability (PIR) and the process two reliability (P2R).

42A IMRP2.K=MLP2G.K/((P1R.K)(P2R.K)) (A101)

Equation A102 defines the initial material input rate to process three (IMRP3) to be equal to the good material leaving process three rate (MLP3G) divided by the product of the process one reliability (P1R), the process two reliability (P2R), and the process three reliability (P3R).

46A IMRP3.K=(MLP3G.K)(1)(1)/((P1R.K)(P2R.K)(P3R.K) (A102)

Equation A103 defines the minimum cash for a process one acquisition index (MC1) to be equal to one if the funds available for investment (FAI) are equal to or greater than the minimum cash required for a process one acquisition (MCP1R); otherwise, it is defined equal to zero.

51A MC1.K=CLIP(1,0,FAI.K,MCP1R) (A103)

Equation A105 defines the process one acquisition desired indicator level (PAD1) to be equal to the process acquisition desired index (PAD) less one.

7A PAD1.K=PAD.K-1 (A105)

Equation A106 defines the process one acquisition index (P1I) to be equal to two if the process one acquisition desired indicator level (PAD1) equals zero; otherwise, it is defined as equal to zero.

49A P1I.K=SWITCH(2,0,PAD1.K) (A106)

Equation A107 defines the process one acquisition index (P1A) to be equal to the sum of the minimum cash for a process one acquisition index (MC1), the process one acquisition index (P1I), and minus three.

8A P1A.K=MC1.K+P1I.K-3 (A107)

Equation A108 defines the process one equipment acquisition quantity (P1EAQ) to be equal to one if the process one acquisition index (P1A) is equal to zero; otherwise, it is defined as equal to zero.

49R P1EAQ.KL=SWITCH(1,0,P1A.K) (A108)

The above formulation accomplishes the following: (1) if PAD equals one, then PAD1 equals zero, (2) if PAD equals zero, then P1I equals two, (3) if MC1 equals one and P1I equals two, then P1A equals zero, and (4) if P1A equals zero, then P1EAQ equals one; otherwise, P1EAQ equals zero. Effectively, therefore, an acquisition can only be made to process one if: (1) process one has been selected as the limiting process, and (2) there are sufficient funds for investing in a process one unit of equipment.

Equation A109 defines the cash effect of a process one equipment acquisition (CP1EA) to be equal to the minimum cash required for a process one acquisition (MCP1R) if the process one acquisition index (P1A) is equal to zero; otherwise, it is defined as equal to zero.

49A CP1EA.K=SWITCH(MCP1R,0,P1A.K) (A109)

Equations A110 to A123 inclusive are formulations similar to the above for processes two and three.

Factory Labor Apportionment Sector

This sector of Model A was developed to apportion available labor to specific processes on some rational basis. When sufficient labor exists relative to total process equipment demands for labor, each process possesses sufficient factory labor and material flow is not restricted by available labor. When insufficient factory labor exists, however, the rationale employed in the model formulation is that the process limiting material flow through all processes receives all of the factory labor it demands, and the remaining factory labor is apportioned to the two remaining processes in proportion to their relative production capabilities. This formulation assumes that interdepartmental shifts of factory labor are made by the company as process needs demand and that sufficient factory personnel are trained in more than one job as to make the shifting possible. Figure 6 is a flow diagram for the factory labor apportionment sector of Model A.

Equation A124 defines the labor apportionment basis indicator (LP) to be equal to five if the effective factory labor available (EFL) is equal to or greater than the total labor required (TLR); otherwise, it is defined as equal to zero. Effective factory labor available (EFL) is defined in the factory labor sector.

51A LP.K=CLIP(5,0,EFL.K,TLR.K) (A124)

Equation A125 defines the total labor required (TLR) to be equal to the sum of the critical process labor amount for each of the three processes (CP1LA, CP2LA, and CP3LA).

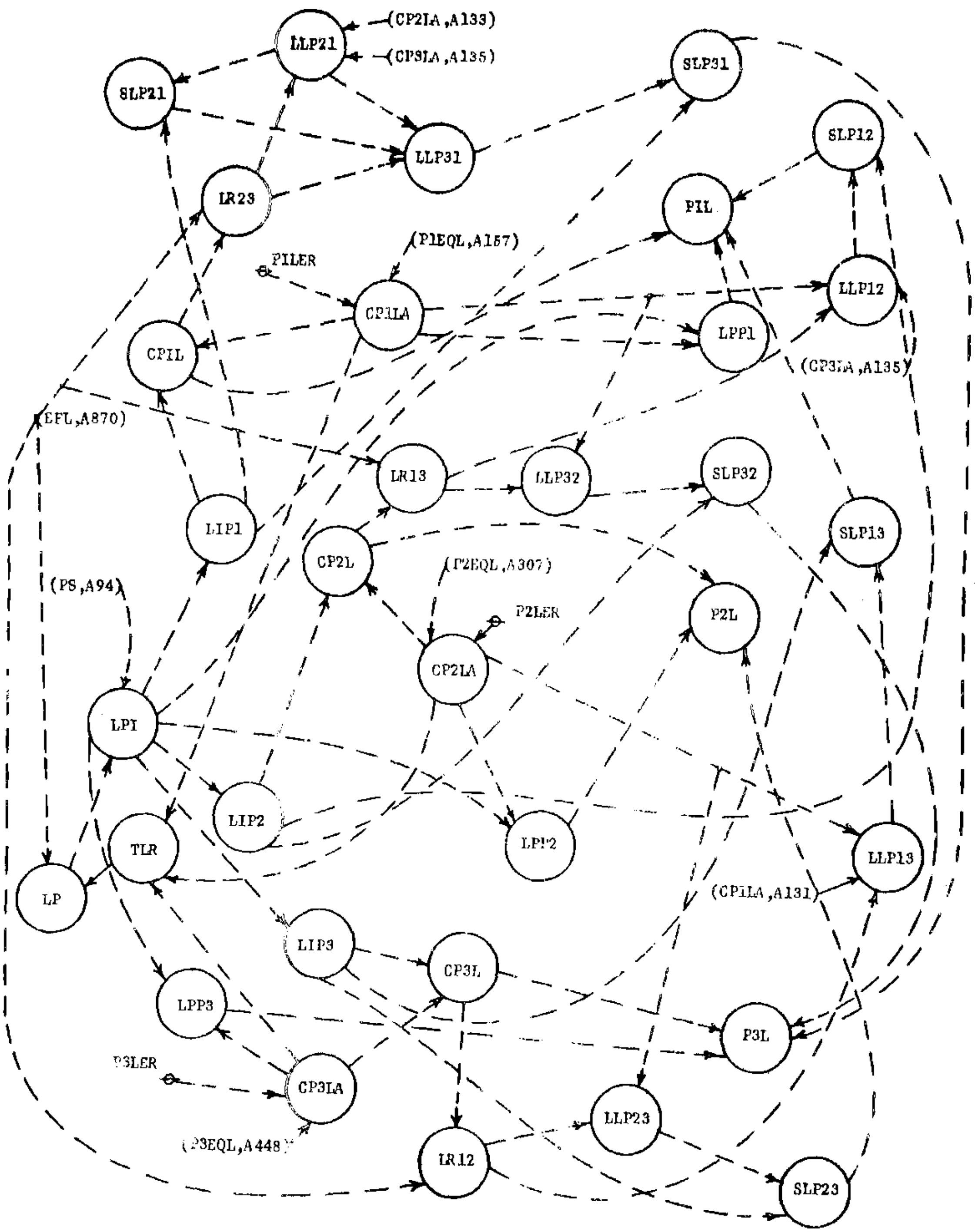
8A TLR.K=CP1LA.K+CP2LA.K+CP3LA.K (A125)

Equation A126 defines the labor apportionment index (LPI) to be equal to the sum of the labor apportionment basis indicator (LP) and the process selected (PS).

7A LPI.K=LP.K+PS.K (A126)

Equation A127 defines the labor indicator for process one (LP1) to be equal to the labor apportionment index (LPI) minus one.

7A LIP1.K=LPI.K-1 (A127)



Figu e 6. A Flow Diagram of the Factory Labor

Apportionment Sector of Model A

In a similar manner, equations A128 and A129 define the labor indicator for process two (LIP2) and the labor indicator for process three (LIP3) to be equal to the labor apportionment index (LPI) minus two and three, respectively.

7A LIP2.K=LPI.K-2 (A128)

7A LIP3.K=LPI.K-3 (A129)

Equation A130 defines the critical process one labor (CP1L) to be equal to the critical process one labor amount (CP1LA) if the labor indicator for process one (LIP1) is equal to zero; otherwise, it is defined as equal to zero.

49A CP1L.K=SWITCH(CP1LA.K,0,LIP1.K) (A130)

Equation A131 defines the critical process one labor required (CP1LA) to be equal to the product of the process one equipment quantity level (P1EQL) and the process one labor to equipment ratio (P1LER).

12A CP1LA.K=(P1EQL.K)(P1LER) (A131)

Equations A132 and A135 inclusive are formulations similar to the above for processes two and three.

The above formulations (i.e., equations A124 to 135 inclusive) accomplish the following: (1) if EFL is equal to or in excess of TLR, LP is assigned a value of five; consequently LPI is assigned a value of at least five, and because LIP1, LIP2 and LIP3 are non-zero this results in CP1L, CP2L and CP3L all being assigned the value zero, and (2) if, however, EFL is less than TLR, insufficient labor exists to fully man all three processes. For example, of process two is assumed to be the critical process under the insufficient labor condition, PS would be assigned the value 2, LP the value 0, and LPI the value 2. As a result, LIP2 would be assigned the value zero, causing CP1L to be assigned a value equal to CP1LA.

Equation A136 defines the labor provided to process one (LPP1) to be equal to the critical process one labor amount (CP1LA) if the labor apportionment index (LPI) is equal to or greater than five; otherwise, it is defined as equal to zero. Equations A137 and A138 similarly define the labor provided to processes two and three (LPP2, LPP3), respectively.

51A	LPP1.K=CLIP(CP1LA.K,0,LPI.K,5)	(A136)
51A	LPP2.K=CLIP(CP2LA.K,0,LPI.K,5)	(A137)
51A	LPP3.K=CLIP(CP3LA.K,0,LPI.K,5)	(A138)

Equation A139 defines the labor remaining for processes two and three (LR23) to be equal to the effective factory labor available (EFL) less the critical process one labor (CP1L). Equations A140 and A141 in a similar manner define the labor remaining for processes one and three (LR13) and the labor remaining for processes one and two (LR12), respectively.

7A	LR23.K=EFL.K-CP1L.K	(A139)
7A	LR13.K=EFL.K-CP2L.K	(A140)
7A	LR12.K=EFL.K-CP3L.K	(A141)

Equation A142 defines the labor left for process one, of process two is critical, (LLP12) to be equal to the product of the critical process one labor amount (CP1LA) and the labor remaining for processes one and three (LR13) divided by the sum of the critical process one labor amount (CP1LA) and the critical process three labor amount (CP3LA). Therefore, a fraction of the labor remaining for processes one and three (LP13) in proportion to the relative capacity of process one compared to process three (i.e., (LR13.K)(CP1LA)/(CP1LA+CP3LA) is assigned to process one if process two is critical.

50A LLP12.K=(CP1LA.K)(LR13.K)/(CP1LA.K+CP3LA.K) (A142)

Equations A143 to A147 inclusive were similarly defined.

Equation A148 defines process one labor (P1L) to be equal to the sum of the critical process labor (CP1L), the labor provided to process one (LPP1), the shared labor for process one if process two is critical (SLP12), and the shared labor for process one if process three is critical (SLP13).

9A P1L.K=CP1L.K+LPP1.K+SLP12.K+SLP13.K (A148)

Equation A149 defines the shared labor for process one if process two is critical (SLP12) to be equal to the labor left for process one if process two is critical (LLP12) if the labor indicator for process two (LIP2) is equal to zero; otherwise, it is defined as equal to zero.

49A SLP12.K=SWITCH(LLP12.K,0,LIP2.K) (A149)

Equations A150 to A156 inclusive are formulated similarly to either equation A148 or A149 for the remaining process combinations.

With respect to equation A148, if sufficient labor exists relative to the total process demand for labor, terms CPiL, SLP12 and SLP13 are all equal to zero, and process one labor (P1L) is equal to LPP1, which in turn is equal to CP1LA (e.g., the process one equipment demand for labor). If, on the other hand, insufficient labor exists relative to the total process demand for labor, the process one labor (P1L) equals one of the following: (1) if process one is the critical process, LPP1 is equal to zero, both of the shared labor terms are equal to zero, and process one labor (P1L) equals CP1L, which in turn equals CP1LA; or (2) if process one is not the critical process, then LPP1, CP1L and one of the shared labor terms are all equal to zero, and the remaining shared labor term (e.g., SLP12 if process two is the critical process) determines the extent of process one labor (P1L).

Acquired Processing Equipment Sector

This sector contains formulations for equipment characteristics, as indicated for initial equipment, for a maximum of five additional units for each process. At the beginning of the simulation period, all acquired processing equipment formulations are inactive and do not influence the material flow, labor, cost or other sectors of the model. As the process acquisition selection sector signals the purchase of an additional processing unit, a time sequence is initiated for a new unit of equipment for the process indicated. The full range of characteristics for the added machine unit becomes effective, resulting in an increased material flow capability, a demand for additional factory labor, and an adjustment of the process scrap rate and total equipment expense. These effects cause other indirect adjustments throughout the model. Figure 7 is a flow diagram for the acquired processing equipment sector of Model A.

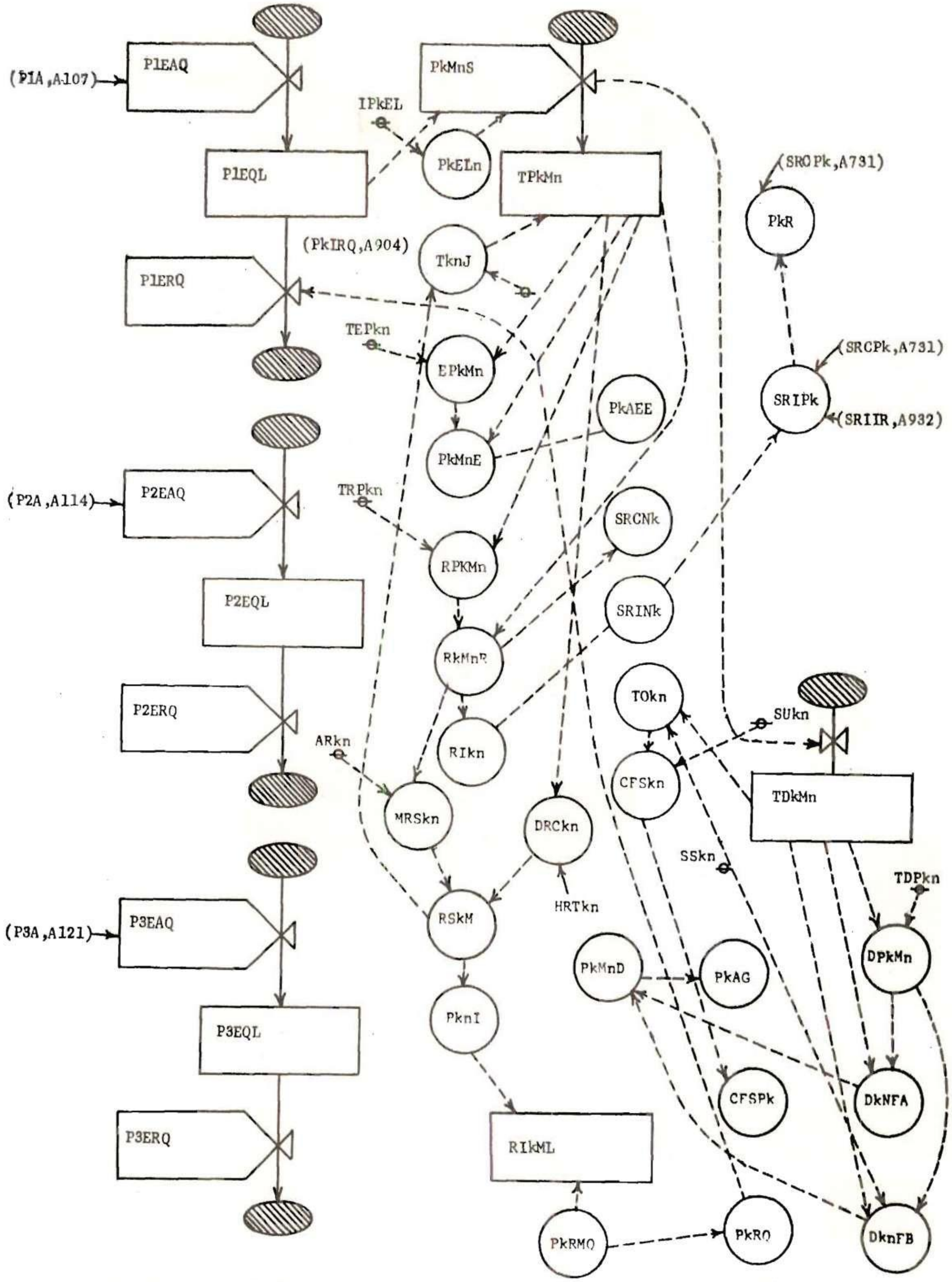


Figure 7. A Flow Diagram of the Acquired Processing
Equipment Sector of Model A

This sector and the one which follows describe the detailed formulations for individual processing units either acquired after specification of initial conditions or in service at the time of initial condition specification. This sector is detailed to the extent of n processing units in k processes for units acquired during the simulation period. Since there are three processes, k in the detailed formulation takes on a value of one, two or three in accordance with the particular process under consideration. The formulation capacity relative to individual processing units is five for each process, for units acquired during the simulation period.

Since equations in this and the following sector are similarly formulated for multiples of units in different processes, the following description will be made only for process unit number one of process one. In all instances, a single digit in a variable definition refers to a process, whereas two digits in a variable definition identify process and then process unit in that order.

Equation A157 defines the process one equipment quantity level (P1EQL) at time K to be equal to the process one equipment quantity level at time J plus the difference between the process one equipment acquisition quantity (P1EAQ) and the process one equipment retirement quantity (P1ERQ) for the interval JK.

1L P1EQL.K=P1EQL.J+(DT)(P1EAQ.JK-P1ERQ.JK) (A157)

Equation A158 defines the process one machine one signal (P1M1S) to be equal to one if the process one equipment quantity level (P1EQL) is equal to or greater than the process one initial equipment level plus one

(P1EL1); otherwise, it is defined as equal to zero.

51R P1M1S.KL=CLIP(1,0,P1EQL.K,P1EL1.K) (A158)

Equation A159 defines process one initial equipment level plus one (P1EL1) to be equal to the initial process one equipment level (IP1EL) plus one.

7A P1EL1.K=IP1EL+1 (A159)

Equation A161 defines the timing for process one machine one (TP1M1) at time K to be equal to the timing for process one machine one at time J plus the sum of the process one machine one signal (P1M1S) and the timing jump for process one machine one (T11J).

1L TP1M1.K=TP1M1.J+(DT)(P1M1S.JK+T11J.J) (A161)

Equation A162 defines the expense for process one machine one (EP1M1) to be a table function of timing for process one machine one (TP1M1) starting at zero weeks and ending with 260 weeks in increments of 26 weeks. Equation A163 assigns table values to expense for process one machine one (EP1M1) corresponding to the above incremental values of timing for process one machine one (TP1M1).

58A EP1M1.K=TABHL(TEP11,TP1M1.K,0,260,26) (A162)

C TEP11*=60/50/45/52/75/105/140/187/240/290/0 (A163)

Equation A164 defines process one machine one actual expense (P1M1E) to be equal to expense for process one machine one (EP1M1) if timing for process one machine one (TP1M1) is equal to or greater than one; otherwise, it is defined as equal to zero.

51A P1M1E.K=CLIP(EP1M1.K,0,TP1M1.K,1) (A164)

Equations A157 to A164 inclusive accomplish the following: (1) the process one equipment quantity level (P1EQL) is determined as a result of addition or retirement of an equipment unit in process one; (2) the process one machine one signal (P1M1S) takes on the value of one at such time as that particular unit is brought into the active simulation model, which starts a timing level (TP1M1) initially defined as zero; and (3) actual equipment expense (EP1M1) remains zero until the timing level takes on a value greater than zero. At time one for TP1M1 the actual equipment expense is defined as equal to the tabled equipment expense (EP1M1) of $60. The timing jump for process one machine one (T11J) will be described in the replacement portion of this sector.

Equations A165 to A184 inclusive are similar formulations for additional processing units in process one.

Equation A185 defines the reliability for process one machine one (RP1M1) to be a table function of the timing for process one machine one (TP1M1), starting with zero weeks and ending with 260 weeks in increments of 26 weeks. Equation A186 assigns table values to the reliability of process one machine one (RP1M1) corresponding to the above incremental values of timing for process one machine one (TP1M1).

58A RP1M1.K=TABHL(TRP11,TP1M1.K,0,260,26) (A185)

C TRP11*=.5/.8/.9/.95/.95/.95/.95/.9/.85/.60/0 (A186)

Equation A187 defines the process one machine one actual reliability (P1M1R) to be equal to the reliability of process one machine one (RP1M1) if the timing for process one machine one (TP1M1) is equal to or greater than one; otherwise, it is defined as equal to zero.

51A P1M1R.K=CLIP(RP1M1.K,0,TP1M1.K,1) (A187)

Equation A196 defines the sum of reliability values for process one (SRCN1) to be equal to the sum of the individual process unit reliability values for a given process.

10A SRCN1.K=P1M1R.K+P1M2R.K+P1M3R.K+P1M5R.K+0 (A196)

Equation A197 defines the reliability unit indicator for process one machine one (RI11) to be equal to zero if the process one machine one actual reliability (P1M1R) equals zero; otherwise, it is defined as equal to one.

49A RI11.K=SWITCH(0,1,P1M1R.K) (A197)

Equation A202 defines the sum of the reliability unit indicators for process one (SRIN1) to be equal to the sum of the individual reliability unit indicators for process one.

10A SRIN1.K=RI11.K+RI12.K+RI13.K+RI15.K+0 (A202)

Equation A203 defines process one reliability (P1R) to be equal to the total sum of reliability values for process one (SRCP1) divided by the sum of reliability unit indicator values for process one (SRIP1). Process one reliability (P1R) expresses average reliability for all units in process one, including initial as well as acquired units; therefore, definition of variables SRCP1 and SRIP1 will be deferred until description of the initial equipment sector.

20A P1R.K=SRCP1.K/SRIP1.K (A203)

Throughout the model formulation, reliability is defined as the decimal equivalent of the percentage of good material leaving a process as compared to the total amount of material entering the process. It is assumed that all bad material is scrap and not reworkable.

Equations A185 to A203 inclusive were formulated to accomplish the following: (1) RP1M1 represents a tabled value of reliability as a function of equipment life, which is initially zero and remains zero until such time as the timing function for a particular processing unit is increased to a value of one; (2) when TR1M1 is equal to or greater than one, the actual reliability variable (i.e., P1M1R) takes on the tabled reliability value; (3) the reliability unit indicator for the unit increases from zero to one; and (4) average process reliability is determined by adding all processing unit reliability values and dividing by the sum of each processing unit's corresponding reliability unit indicator value.

Equation A204 defines the timing for depreciation for process one machine one (TD1M1) at time K to be equal to the timing for depreciation for process one machine one at time J plus the sum of the process one machine one signal (P1M1S) and the timing jump for process one machine one (T11J).

1L TD1M1.K=TD1M1.J+(DT)(P1M1S.JK+T11J.J) (A204)

A separate timing function for depreciation (TD1M1) was developed as a parallel formulation to the process unit timing function (TP1M1) to allow sufficient flexibility in policy alternative selection to permit depreciation to continue after a unit had been retired from active service. All policy alternatives employed in this model assumed that depreciation ended at the time of unit retirement; therefore, the depreciation and process timing functions performed identical functions, and one of the timing functions could have been eliminated.

Equation A205 defines the depreciation for process one machine one (DP1M1) to be a table function of the timing for depreciation for process one machine one (TD1M1) starting with zero weeks and ending with 234 weeks in increments of 26 weeks. Equation A206 assigns table values to depreciation for process one machine one (DP1M1) corresponding to the above incremental values of timing for depreciation for process one machine one (TD1M1).

```
58A     DP1M1.K=TABHL(TDP11,TD1M1.K,0,234,26)                    (A205)
C       TDP11*=100/100/100/100/100/100/100/100/100/0             (A206)
```

Equation A207 defines depreciation for process one machine one factor A (D11FA) to be equal to depreciation for process one machine one (DP1M1) if timing for depreciation for process one machine one (TD1M1) is equal to or greater than one; otherwise, it is defined as equal to zero.

```
51A     D11FA.K=CLIP(DP1M1.K,0,TD1M1.K,1)                        (A207)
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Equation A208 defines depreciation for process one machine one factor B (D11FB) to be equal to depreciation for process one machine one

(DP1M1) if the timing for depreciation for process one machine one (TD1M1) is equal to or greater than the salvage signal for process one machine one (SS11); otherwise, it is defined as equal to zero.

51A D11FB.K=CLIP(DP1M1.K,0,TD1M1.K,SS11) (A208)

Equation A209 defines the process one machine one actual depreciation (P1M1D) to be equal to the difference between the depreciation for process one machine one factor A (D11FA) and the depreciation for process one machine one factor B (D11FB).

7A P1M1D.K=D11FA.K-D11FB.K (A209)

Equation A210 defines the timing to stop depreciation for process one machine one (TD11) to be equal to the timing for depreciation for process one machine one (TD1M1) less the salvage signal for process one machine one (SS11).

7A TD11.K=TD1M1.K-SS11 (A210)

Equation A212 defines the cash from salvage of process one machine one (CFS11) to be equal to the salvage value of process one machine one (SV11) if timing to stop depreciation for process one machine one (TD11) is zero; otherwise, it is defined as equal to zero.

49A CFS11.K=SWITCH(SV11,0,TD11.K) (A212)

Equations A204 to A212 inclusive were formulated to accomplish the following: (1) to provide a timing level for depreciation (e.g., TD1M1), (2) to provide table functions of depreciation for individual units as a function of time, (3) to provide a means for stopping depreciation at time of salvage, and (4) to provide the means for increasing cash by the salvage value amount at the time of equipment salvage.

Equation A259 defines the cash from salvage for acquired process one equipment (CFSP1) to be equal to the sum of the individual processing unit cash from salvage values.

10A CFSP1.K=CFS11.K+CFS12.K+CFS13.K+CFS14.K+CFS15.K+0 (A259)

Equation A260 defines the process one machine one retirement quantity (P11RQ) to be equal to one if the replacement indicator for process one machine one level (RI11L.K) is equal to zero; otherwise, it is defined as equal to zero.

49A P11RQ.K=SWITCH(1,0,RI11L.K) (A260)

Equation A261 defines the replacement indicator for process one machine one level, (RI11L) at time K to be equal to the replacement indicator for process one machine one level at time J plus one less the replacement indicator for process one machine one (R11I) plus the process one machine one retirement quantity (P11RQ) for interval JK.

52L RI11L.K=RI11L.J+(DT)(1-R11I.J+P11RQ.J+0) (A261)

Equation A262 defines the retirement signal for process one machine one (RS11) to be equal to the sum of the minimum allowed reliability check for process one machine one (DRC11).

7A RS11.K=MRS11.K+DRC11.K (A262)

The minimum reliability signal for process one machine one (MRS11) represents an alternate policy variable in the revised policy portion of this research; therefore, although its definition should logically follow equation A262, its description will be included in the policy variables sector.

Equation A263 defines the decreasing reliability check for process one machine one (DRC11) to be equal to zero if the timing for process one machine one (TP1M1) is equal to or greater than the high reliability point for process one machine one (HRT11); otherwise, it is defined as equal to one.

51A DRC11.K=CLIP(0,1,TP1M1.K,HRT11) (A263)

Equation A266 defines the timing jump for process one machine one (T11J) to be equal to the minimum machine life for process one (MMLP1) if the retirement signal for process one machine one (RS11) is equal to zero; otherwise, it is defined as equal to zero.

49A T11J.K=SWITCH(MMLP1,0,RS11.K) (A266)

Equation A268 defines the retirement indicator for process one machine one (R11I) to be equal to one if the retirement signal for process one machine one (RS11) is equal to or greater than one; otherwise, it is defined as equal to zero.

51A R11I.K=CLIP(1,0,RS11.K,1) (A268)

Equations A260 to A268 inclusive permit the following conditional retirement of a unit of processing equipment. The process one machine one retirement quantity (11RQ) takes on the value one at the sole point in time when the replacement indicator for process one machine one level becomes zero. When the reliability level of a machine falls below the defined minimum reliability level, the minimum reliability signal (MRS11) takes on the value zero. The decreasing reliability check (DRC11) takes on the value zero when the machine has been in service beyond the highest reliability point time (HRT11) distinguishing between a machine wearing out in time as compared with a machine improving its reliability in its initial break-in period. Those two concurrent conditions cause the retirement signal (RS11) to take on a value of zero, sequentially causing the retirement indicator to take on the value of zero, which allows the replacement indicator for process one machine one level to increase by one to zero, at which point the unique replacement indicator level of zero causes the retirement of the processing unit.

Initial Processing Equipment Sector

This sector contains formulations for specifying individual equipment characteristics for each machine in operation at the initiation of the simulation period. Characteristics considered in the formulation for each equipment unit include scrap rate as a function of age, processing unit expense as a function of age, depreciation as a function of age, replacement characteristics, initial cost, and final processing unit scrap value. Units of equipment in excess of an initial process unit quantity specification, but within the formulation capacity, remain inactive throughout the simulation period and have no effect on simulation results. Figure 8 is a flow diagram for the initial process equipment sector of Model A.

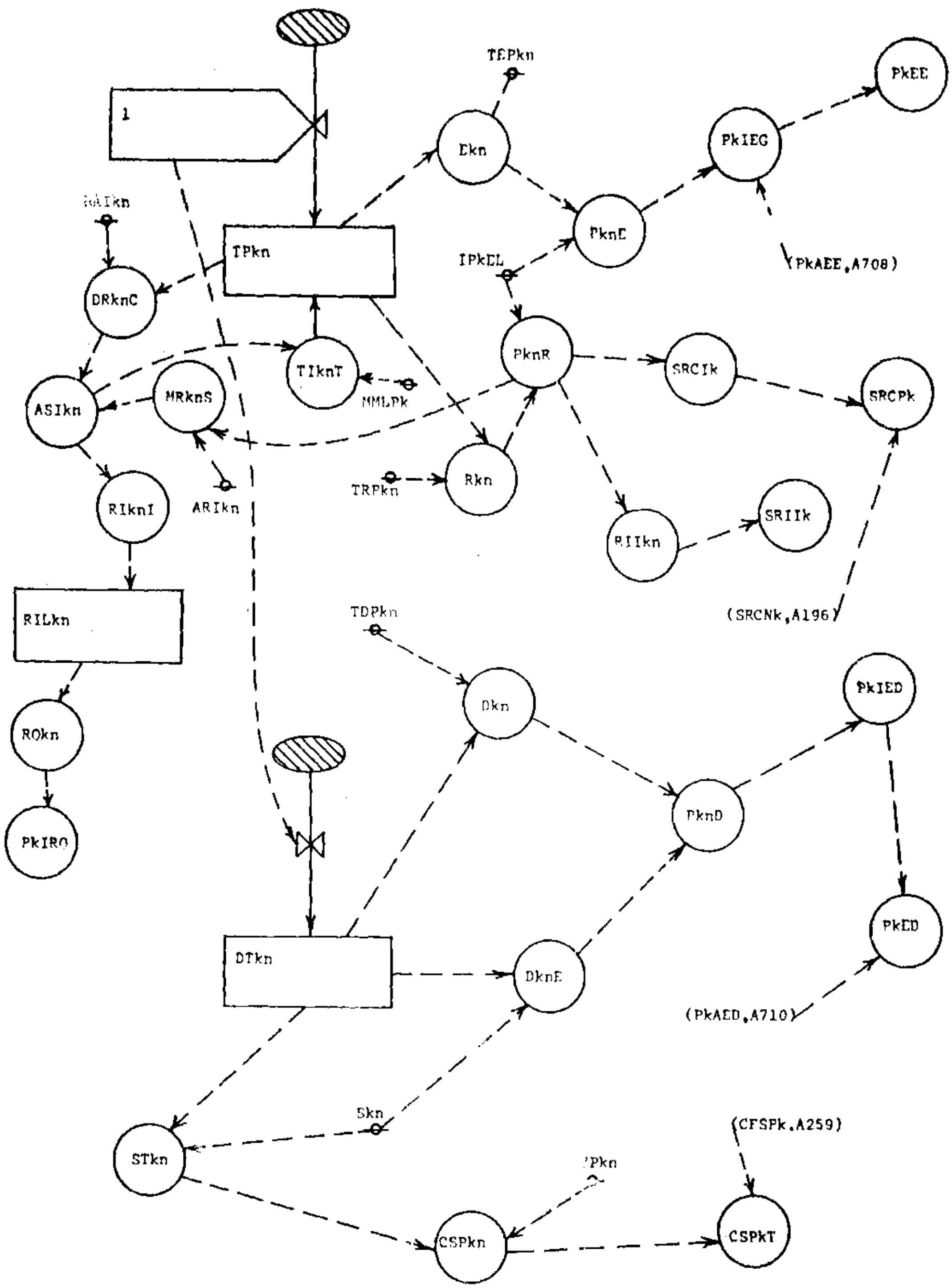


Figure 8 A Flow Diagram of the Initial Processing Equipment Sector of Model A

Since the detailed formulation for this sector closely parallels the formulation for the previous sector, the following description in this sector assumes a detailed understanding of the previous sector.

Initial equipment refers to those units of processing capacity in service at the time of initial condition specification. Therefore, initial units are not sequentially brought into the active simulation as in the previous sector, but are at some initially defined point relative to their respective timing functions. Whereas the timing for process one machine one (TP1M1) is initially defined to be equal to zero, as are all timing functions for acquired equipment timing for process one machine one initial equipment (TP11), for example, is initially defined as equal to 156 weeks, or three years old. All other timing functions for initial equipment are similarly specified as to initial time values.

The initial processing unit capacity differs for each process. The formulation has an initial equipment unit capacity of four, three and two units for processes one, two and three, respectively. The process one formulation for initial equipment is complete for five processing units except for the initial condition equation number A1023, which considers only four processing units, limiting the process one unit capacity to four. The limitation is a consequence of an equation form limitation which could have been circumvented by defining additional dummy variables. Since the model is hypotehtical, the limitation to four units was not considered detrimental.

Equation A705 defines the total process one equipment retirement quantity (P1ERQ) to be equal to the sum of the process one retirement quantity for initial equipment (P11RQ) and the acquired process one retirement quantity (P1RQ).

7R P1ERQ.KL=P1IRQ.K+P1RQ.K (A705)

Equation A706 defines the total process one equipment expense (P1EE) to be the sum of the process one initial equipment expense (P1IEE) and the process one acquired equipment expense (P1AEE).

7A P1EE.K=P1IEE.K+P1AEE.K (A706)

Equation A731 defines the sum of reliability values for process one (SRCP1) to be equal to the sum of the sum of reliability values for acquired units in process one (SRCN1) and the sum of reliability values for initial units in process one (SRCI1).

7A SRCP1.K=SRCN1.K+SRCI1.K (A731)

Factory Labor Sector

The factory labor acquisition policy employed is based on a comparison of labor demanded by process equipment and the quantity of labor presently available. If factory labor is below the desired level, an additional factory laborer is hired and is assumed to enter the company as a trainee. During the defined training period, it is assumed that he operates at a lower efficiency than a trained laborer. Therefore, labor capability is computed as the sum of trained laborers plus some effectiveness ratio times the number of employees in training, in order to arrive at a total number of equivalent trained laborers. This equivalent number of trained employees is compared with machine labor demands as an input to the hiring decision. Trained labor is assumed to leave the company at a specified turnover rate which continuously requires hiring of additional laborers in an effort to replace employees leaving the company. Figure 9 is a flow diagram of the factory labor sector of Model A.

Equation A858 defines the factory labor required for equipment (FLRFE) to be equal to the sum of the products of the process equipment quantity levels (P1EQL, P2FQL and P3EQL) and their respective process labor to equipment ratios (P1LER, P2LER and P3LER).

16A FLRFE.K=(P1EQL.K)(P1LER)+(P2EQL.K)(P2LER)+(P3EQL.K)(P3LER) +(1)(0) (A858)

Equation A859 defines the factory labor desired (FLD) to be equal to the product of the labor to equipment factor (LTEF) and the factory labor required for equipment (FLRFE).

12A FLD.K=(LTEF)(FLRFE.K) (A859)

Equation A860 defines the factory labor hiring rate (FLHR) to be equal to zero if the factory labor quantity (FLQ) is equal to or greater than the factory labor desired (FLD); otherwise, it is defined as equal to the factory hiring rate with undercapacity (FHRWU).

51R FLHR.KL=CLIP(0,FHRWU.K,FLQ.K,FLD.K) (A860)

Equation A861 defines the factory labor quantity (FLQ) to be equal to the sum of the factory labor in training (FLIT) and the trained factory labor (TFL).

7A FLQ.K=FLIT.K+TFL.K (A861)

Equation A862 defines the factory hiring rate with undercapacity (FHRWU) to be equal to the difference of the factory labor desired (FLD)

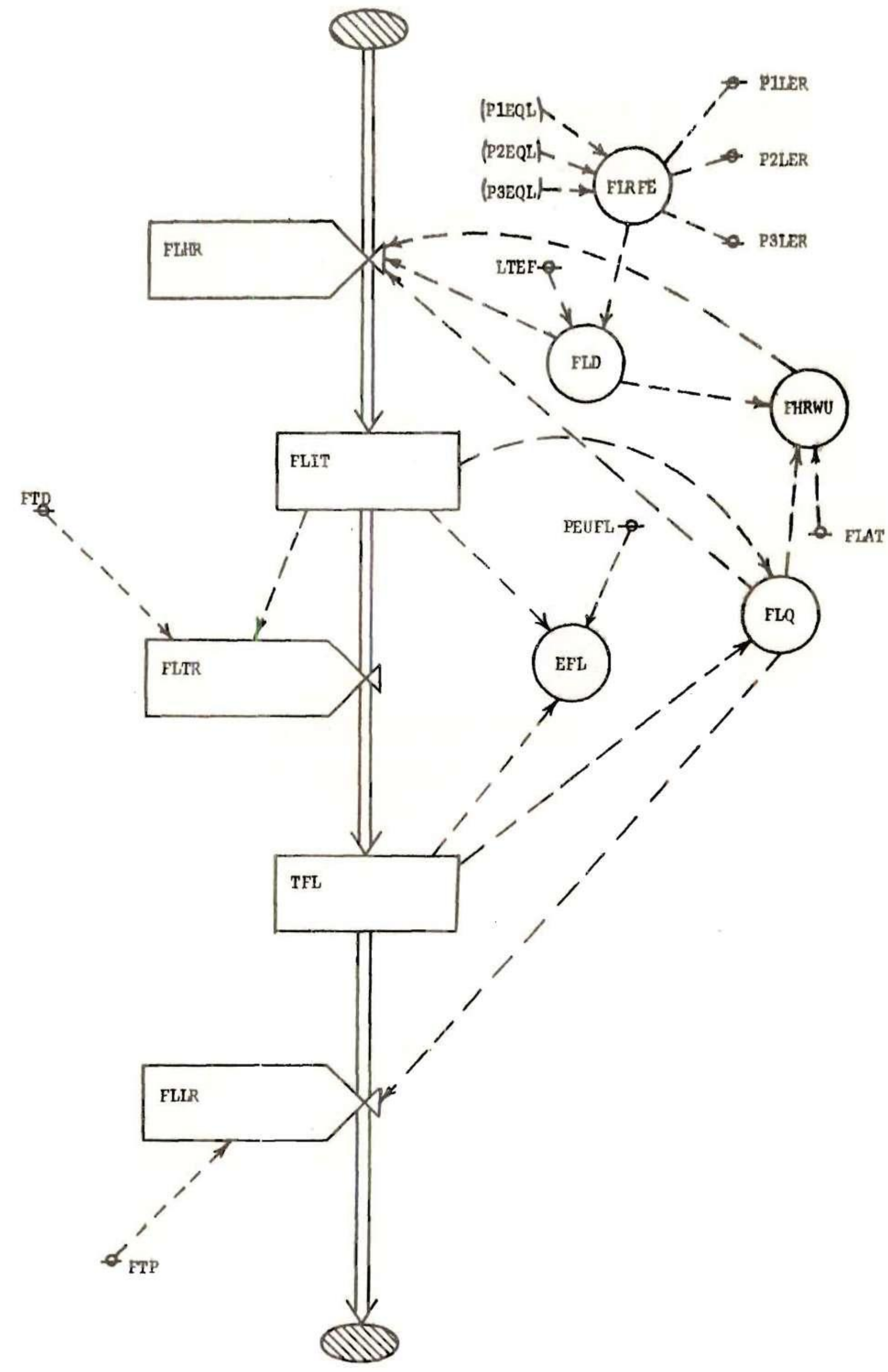


Figure 9. A Flow Diagram of the Factory Labor Sector of Model A

and the factory labor quantity (FLQ) divided by a factory labor averaging time (FLAT).

21A FHRWU.K=(1/FLAT)(FLD.K-FLQ.K) (A862)

Equation A864 defines the factory labor training rate (FLTR) to be equal to the factory labor in training (FLIT) divided by the factory training delay (FTD).

20R FLTR.KL=FLIT.K/FTD (A964)

Equation A866 defines the factory labor in training (FLIT) at time K to be equal to the factory labor in training at time J plus the difference between the factory labor hiring rate (FLHR) and the factory labor training rate (FLTR) for interval JK.

1L FLIT.K=FLIT.J+(DT)(FLHR.JK-FLTR.JK) (A866)

Equation A867 defines the factory labor leaving rate (FLLR) to be equal to the product of the factory turnover percentage (FTP) and the factory labor quantity (FLQ).

12R FLLR.KL=(FTP)(FLQ.K) (A867)

Equation A869 defines the total factory labor (TFL) at time K to be equal to the trained factory labor at time J plus the difference between the factory labor training rate (FLTR) and the factory labor leaving rate (FLLR) during interval JK.

1L TFL.K=TFL.J+(DT)(FLTR.JK-FLLR.JK) (A869)

Equation A870 defines the effective factory labor (EFL) to be equal to the trained factory labor (TFL) plus the product of the percentage effectiveness used for factory labor (PEUFL) and the factory labor in training (FLIT).

15A EFL.K=(1)(TFL.K)+(PEUFL)(FLIT.K) (A870)

Professional Labor Sector

Professional labor capability is formulated as an aggregate, and its desired level is assumed to be a defined constant fraction of the number of factory laborers. In a manner similar to the formulation for factory labor, new professional personnel is assumed to enter the company on a trainee basis and thus only partially effective during the defined training period. Figure 10 is a flow diagram of the professional labor sector of Model A.

Equation A872 defines the professional labor desired (PLD) to be equal to the product of the professional to factory labor ratio desired (PFLRD) and the factory labor quantity (FLQ).

12A PLD.K=(PFLRD)(FLQ.K) (A872)

Equation A874 defines the professional labor hiring rate (PLHR) to be equal to zero if the professional labor quantity (PLQ) is equal to or greater than the professional labor desired (PLD); otherwise, it is defined as equal to the professional hiring rate with undercapacity (PHRWU).

51R PLHR.KL=CLIP(0,PHRWU.K,PLQ.K,PLD.K) (A874)

Equation A875 defines the professional labor quantity (PLQ) to be equal to the sum of the professional labor in training (PLIT) plus the

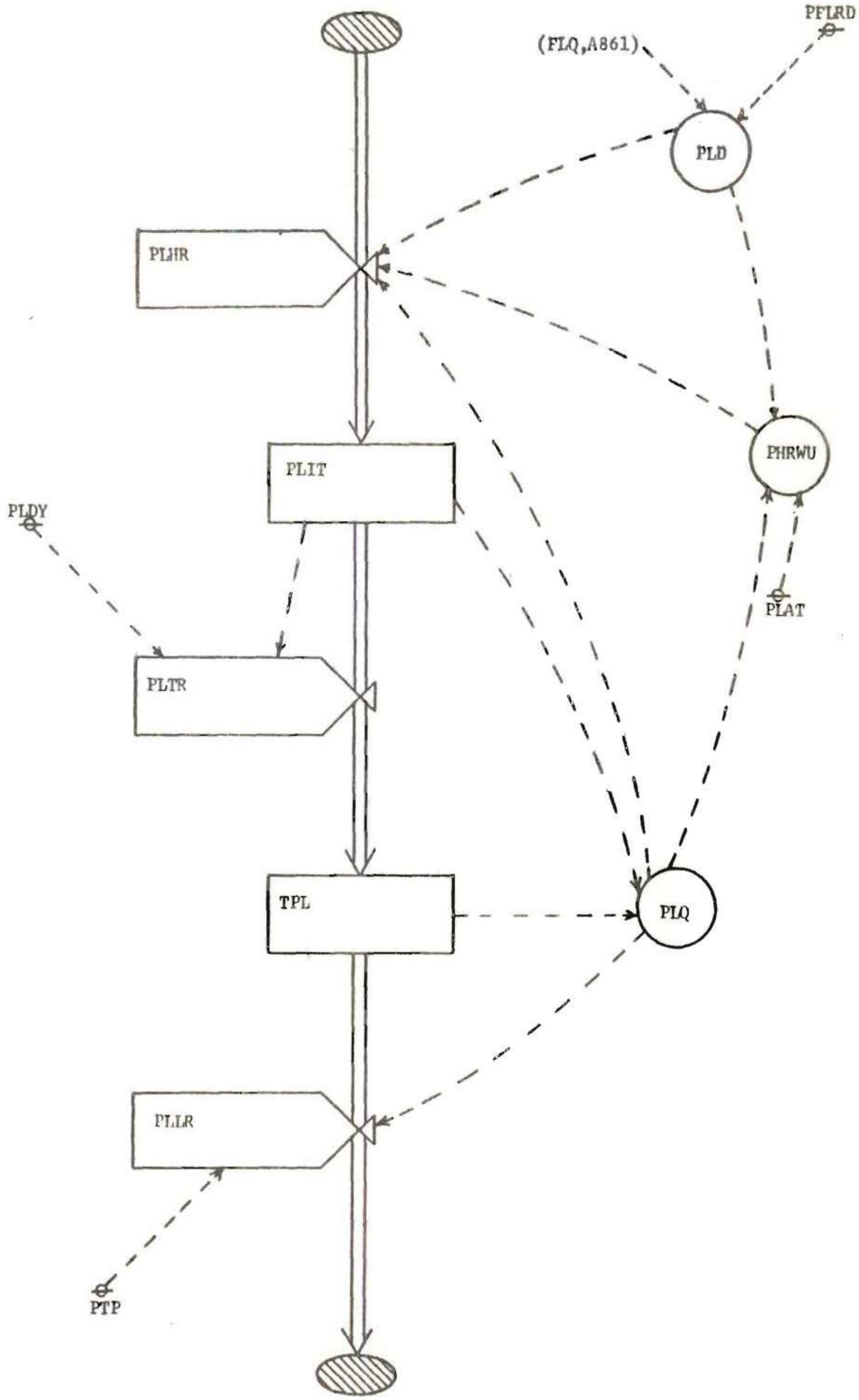


Figure 10. A Flow Diagram of the Professional Labor Sector of Model A

trained professional labor (TPL).

7A PLQ.K=PLIT.K+TPL.K (A875)

Equation A876 defines the professional hiring rate with under-capacity (PHRWU) to be equal to the difference between the professional labor desired (PLD) and the professional labor quantity (PLQ) divided by the professional labor averaging time (PLAT).

21A PHRWU.K=(1/PLAT)(PLD.K-PLQ.K) (A876)

Equation A878 defines the professional labor training rate (PLTR) to be equal to the professional labor in training (PLIT) divided by the professional labor training delay (PLDY).

20R PLTR.KL=PLIT.K/PLDY (A878)

Equation A880 defines the professional labor in training (PLIT) at time K to be equal to the professional labor in training at time J plus the difference between the professional labor hiring rate (PLHR) and the professional labor training rate (PLTR) during interval JK.

1L PLIT.K=PLIT.J+(DT)(PLHR.JK-PLTR.JK) (A880)

Equation A881 defines the professional labor leaving rate (PLLR) to be equal to the product of the professional turnover percentage (PTP) and the professional labor quantity (PLQ).

12R PLLR.KL=(PTP)(PLQ.K) (A881)

Equation A883 defines the trained professional labor (TPL) at time

K to be equal to the trained professional labor at time J plus the difference between the professional labor training rate (PLTR) and the professional labor leaving rate (PLLR) during interval JK.

1L TPL.K=TPL.J+(DT)(PLTR.JK-PLLR.JK) (A883)

Costs Sector

This sector of Model A was developed to provide a means for continuously determining the cash position of the company as well as summing income and expense elements for calculation of profit in the financial sector. The cash position of the firm is assumed to be a major restriction on growth since additional processing units can only be added when sufficient funds are available. The formulation assumes that a minimum cash balance is maintained for short-term operation, if earnings permit, with all funds in excess of the minimum cash balance serving as funds available for investment. Figure 11 is a flow diagram of the costs sector of Model A.

Interest expense is assumed to be the going interest rate for funds made available to the company as defined in the financial sector, times the funded debt level at that time. General and administrative expenses are assumed to be a function of the quantity of factory labor and the average order output rate. Overhead cost is assumed to be the sum of a fixed cost, equipment expenses, and an additional variable cost as a function of the quantity of factory labor. Labor costs are the product of the quantity of employees and the assumed average labor cost per employee for each labor group.

The tax rate is assumed to be 30 per cent for the first $25,000 of

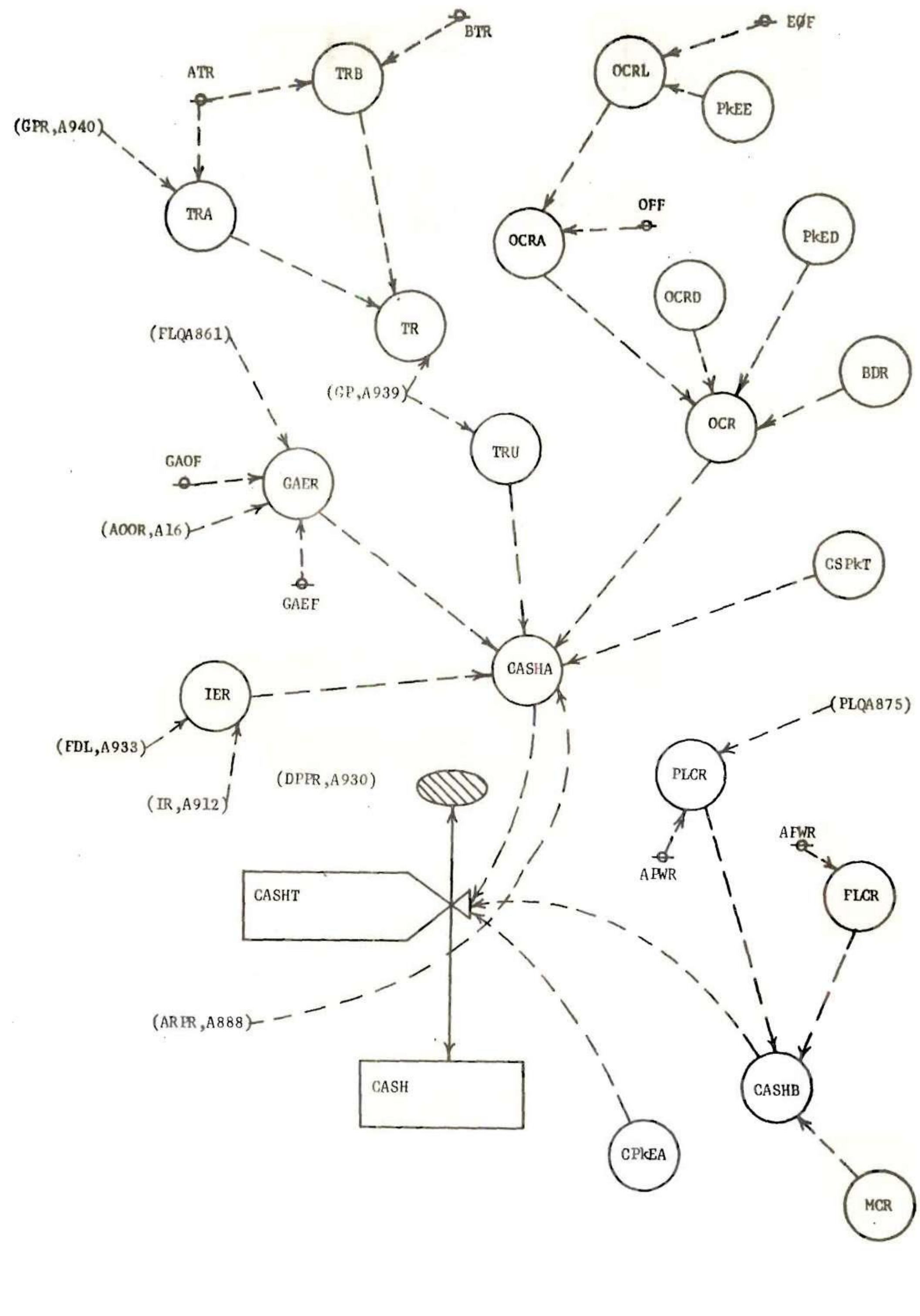


Figure 11. A Flow Diagram of the Costs Sector of Model A

profit per year and 50 per cent for additional annual profits. Net profit before taxes is determined by employing all expenses and incomes developed. Reduction by the applicable tax cost provides a net profit after taxes figure.

Equation A884 defines the cash level (CASH) at time K to be equal to the cash level at time J plus the total cash rate (CASHT) during the interval JK.

1L CASH.K=CASH.J+(DT)(CASHT.JK+0) (A884)

Equation A885 defines the total cash rate (CASHT) to be equal to the sum of the net cash amount A (CASHA), and net cash amount B (CASHB), less the cash for a process one equipment acquisition (CP1EA), a process two equipment acquisition (CP2EA), and a process three equipment acquisition (CP3FA).

10R CASHT.KL=CASHA.K+CASHB.K-CP1EA.K-CP2EA.K-CP3EA.K+0 (A885)

Equation A886 defines the net cash amount A (CASHA) to be equal to the sum of the accounts receivable payment rate (ARPR), the cash from a process one machine salvage (CSP1T), and the cash from a process two machine salvage (CSP2T), less the debt principal payment rate (DPPR), the interest expense rate (IER), the general and administrative expense rate (GAER), the true tax rate used (TRU), and the overhead cost rate (OCR).

11A CASHA.K=ARPR.K-DPPR.K-IER.K-GAER.K-TRU.K-OCR.K
+CSP1T.K+CSP2T.K (A886)

Equation A887 defines the net cash amount B (CASHB) to be equal to the sum of the cash from a process three machine salvage (CSP3T) and the debt capital input rate (DCIR), less the sum of the material cost rate (MCR), the professional labor cost rate (PLCR), and the factory labor cost rate (FLCR).

10A CASHB.K=MCR.K-PLCR.K-FLCR.K+CSP3T.K+DCIR.K-0 (A887)

Equation A888 defines the accounts receivable payment rate (ARPR) to be equal to the accounts receivable (AR) divided by the collection period delay (CPD), less the bad debts expense rate (BDER).

27A ARPR.K=(AR.K/CPD)-BDER.K (A888)

Equation A890 defines the interest expense rate (IER) to be equal to the product of the interest rate (IR) and the funded debt level (FDL) divided by 52.

44A IER.K=(IR.K)(FDL.K)/52 (A890)

Equation A891 defines the general and administrative expense rate (GAER) to be equal to the product of the general and administrative expense factor (GAEF) and the factory labor quantity (FLQ) plus the product of the general and administrative orders factor (GAOF) and the average order output rate (AOOR). This formulation assumes that the general and administrative expense is a linear function of both the amount of factory labor and the order output level.

15A GAER.K=(GAEF)(FLQ.K)+(GAOF)(AOOR.K) (A891)

Equation A894 defines the tax rate used (TRU) to be equal to the tax rate (TR) if the profit rate before taxes (GP) is equal to or greater than zero; otherwise, it is defined as equal to zero.

51A TRU.K=CLIP(TR.K,0,GP.K,0) (A894)

Equation A895 defines the tax rate (TR) to be equal to tax rate B (TRB) if the profit before taxes (GP) is equal to or greater than $25,000; otherwise, it is defined as equal to the tax rate A (TRA).

51A TR.K=CLIP(TRB.K,TRA.K,GP.K,25000) (A895)

Equation A896 defines the tax rate A (TRA) to be equal to the product of the A tax rate (ATR) and the profit before taxes rate (GPR). Therefore, if yearly profit before taxes is less than $25,000, the applicable tax rate is the A tax rate (ATR).

12A TRA.K=(ATR)(GPR.K) (A896)

Equation A898 defines tax rate B (TRB) to be equal to the product of the A tax rate (ATR) and $25,000, plus the product of the B tax rate (BTR) and the additional profit before taxes (AGP), all divided by 52. Therefore, if the yearly profit before taxes is equal to or exceeds $25,000, the first $25,000 is taxed at the A tax rate (ATR), and the income in excess of $25,000 is taxed at the B tax rate (BTR).

22A TRB.K=(1/52)(ATR)(25000)+(BTR)(AGP.K) (A898)

Equation A900 defines the overhead cost rate (OCR) to be equal to the sum of the overhead cost rate A (OCRA) and the overhead cost rate for depreciation (OCRD).

7A OCR.K=OCRA.K+OCRD.K (A900)

Equation A901 defines the overhead cost rate A (OCRA) to be equal to the sum of the overhead vixed cost factor (FF), the overhead cost resulting from labor (OCRL), and process one, two and three equipment expense (P1EE, P2EE and P3EE), respectively.

10A OCRA.K=OFF+OCRL.K+P1EE.K+P2EE.K+P3EE.K+0 (A901)

Equation A903 defines the overhead cost rate resulting from labor (OCRL) to be equal to the product of the effective overhead factor for labor (EOF) and the factory labor quantity (FLQ).

12 OCRL.K=(EOF)(FLQ.K) (A903)

Equation A905 defines the overhead cost rate for depreciation (OCRD) to be equal to the sum of the three process equipment depreciation expense terms (P1ED, P2ED and P3ED) and the building depreciation rate (BDR).

9A OCRD.K=P1ED.K+P2ED.K+P3ED.K+BDR.K (A905)

Equation A906 defines the material cost rate (MCR) to be equal to the accounts payable payment rate (APPR).

6A MCR.K=APPR.K (A906)

Equation A907 defines the professional labor cost rate (PLCR) to be equal to the product of the average professional wage rate (APWR) and the professional labor quantity (PLQ).

12A PLCR.K=(APWR)(PLQ.K) (A907)

Equation A909 defines the factory labor cost rate (FLCR) to be equal to the product of the average factory wage rate (AFWR) and the factory labor quantity (FLQ).

A909 FLCR.K=(AFWR)(FLQ.K) (A909)

Financial Sector

The financial sector of the model serves as a means for specifying selected internal financial policies of the firm and accounting relationships which indicate the overall financial condition of the firm. The primary growth variables under consideration in this research are book net worth (NW) and the market net worth (MNW). The formulation for book net worth (NW) is based on standard accounting practice, whereas the formulation for the market net worth (MNW) is based on the second proposition of the Modigliani-Miller (21) cost of capital theory. The market net worth (MNW) is an estimate of the market value of the common shares of the company according to the Modigliani-Miller cost of capital theory.

An underlying assumption in the formulation is that the applicable interest rate is a function of the debt-equity ratio. At debt-equity ratios in excess of specified conservative limits, the interest rate increases rapidly to represent premium interest rates required by lenders. The interest rate cut-off level (IRCO) is a constant in the formulation which must be specified. Interest values are a table function of the debt-equity ratio and also must be specified. Figure 12, a flow diagram of the financial sector of Model A, graphically portrays the interconnections between variables contained in this sector.

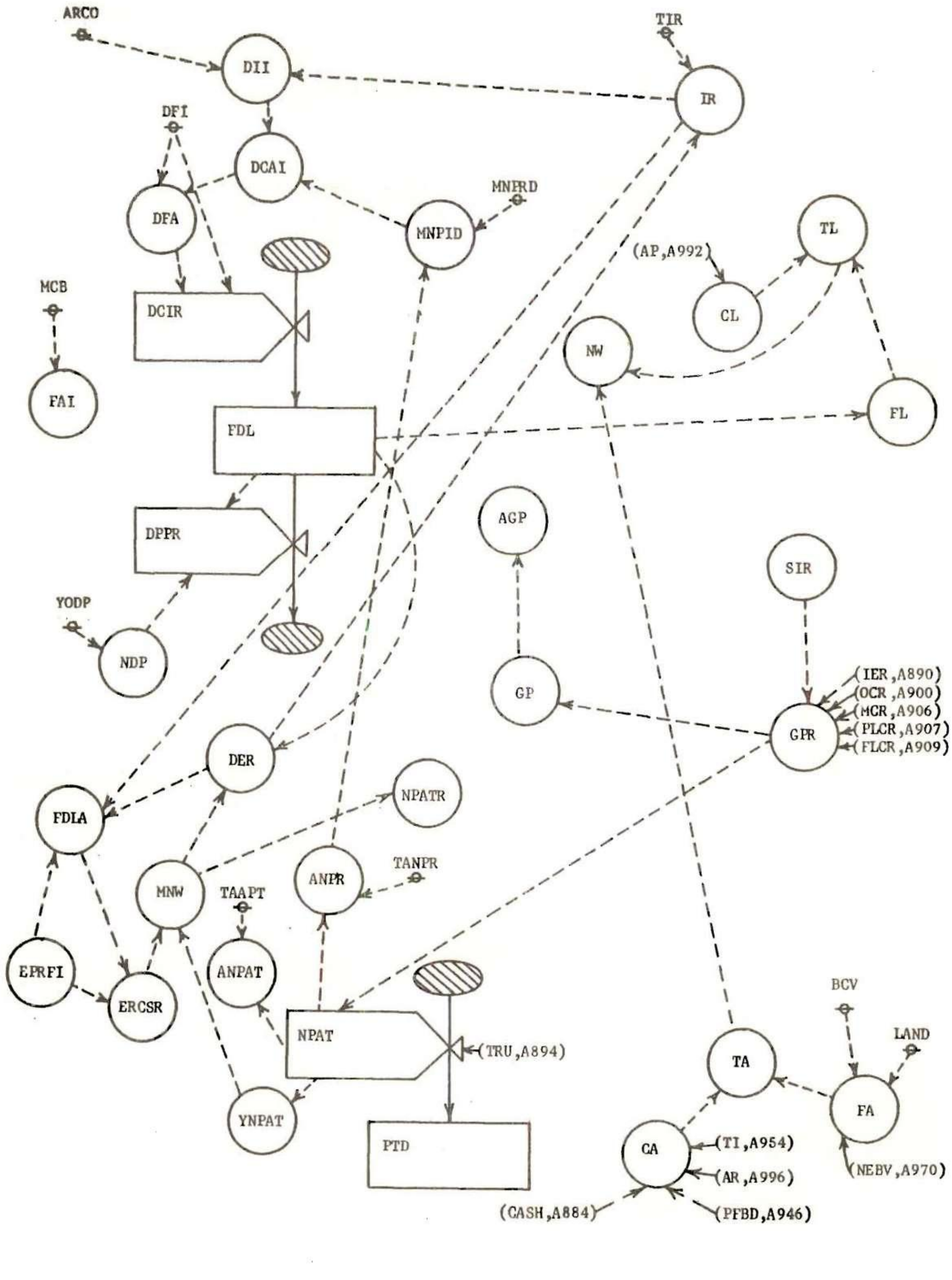


Figure 12. A Flow Diagram of the Financial Sector of Model A

Employing assumed existing policies, additional debt funds can be acquired by the company if three possible limiting conditions have been satisfied. The three conditions are as follows: (1) the present average profit rate must be in excess of a specified minimum profit rate for acquiring additional debt (MNPRD), (2) the applicable interest rate to the company must be below a specified maximum interest rate (IRCO), and (3) funds available for investment (FAI) must be less than the debt fund increment (DFI) to be acquired. If the three conditions are met, a defined increment of debt funds is brought into the firm, and a re-evaluation for possible additional debt acquisition occurs during each successive cycle of the simulation. These three conditions were formulated to assure that debt funds would be acquired only when the need existed for additional debt, the profitability of the company was sufficient to justify additional debt financing, and the interest rate was within specified acceptable limits.

The financial sector does not contain a formulation for dividend expense. Since alternative dividend policy effects were not selected to be considered as part of this research, the simplest dividend policy was selected for the Model A formulation; this policy assumes that dividends are not distributed. The assumption, therefore, is that the owners of the hypothetical company favor internal investment as compared to distribution of possible dividends.

Equation A911 defines the debt-equity ratio (DER) to be equal to the funded debt level (FDL) divided by the market net worth (MNW).

20A DER.K=FDL.K/MNW.K (A911)

Equation A812 defines the interest rate (IR) to be a table function of the debt-equity ratio (DER), starting at zero and ending with 0.7 in increments of 0.1. Equation A913 assigns table values to the interest rate (IR) corresponding to the above incremental values of the debt-equity ratio (DER).

58A IR.K=TABHL(TIR, DER.K,0,0.7,0.1) (A912)

C TIR*=0.06/0.065/0.07/0.08/0.095/0.12/0.15/0.25 (A913)

Equation A914 defines the market net worth (MNW) to be equal to the yearly net profit after taxes (YNPAT) divided by the expected return from a common share rate (ERCSR).

20A MNW.K=YNPAT.K/ERCSR.JK (A914)

Equation A915 defines the yearly net profit after taxes (YNPAT) to be equal to the product of the average net profit after taxes (ANPAT) and 52.

12A YNPAT.K=(ANPAT.K)(52) (A915)

Equation A916 defines the average net profit after taxes (ANPAT) at time K to be equal to the average net profit after taxes at time J plus the difference between the net profit after taxes (NPAT) and the average net profit after taxes (ANPAT) divided by the time to average the average profit after taxes (TAAPT).

3L ANPAT.K=ANPAT.J+(DT)(1/TAAPT)(NPAT.J-ANPAT.J) (A916)

Equation A918 defines the expected after-tax return from a common share rate (ERCSR) to be equal to the sum of the expected after tax profit rate for the industry (EPRFI) and the after-tax funded debt level adjustment (FDLA).

7R ERCSR.KL=EPRFI+FDLA.K (A918)

Equation A920 defines the after-tax funded debt level adjustment (FDLA) to be equal to the product of the debt-equity ratio (DER) and the difference between the expected after-tax profit rate for the industry (EPRFI) and the interest rate (IR).

18A FDLA.K=(DER.K)(EPRFI-IR.K) (A920)

Equations A914 to A920 inclusive were formulated to provide a measure of the market net worth. Since Modigliani and Miller (21) have developed a measure of the market net worth, the formulation was developed to incorporate their measure. Modigliani and Miller (21) list the following two equations, which are employed in the formulation:

$$V_j = (S_j - D_j) = \bar{X}_j^{\tau}/\rho_K^{\tau}$$

where $\bar{X}_j$ is the total income net of taxes of the jth firm in risk class k and ρ_K^{τ} is the capitalization rate for income net of taxes in risk class k. The other equation is:

$$i_j = \rho^{\tau} + (\rho^{\tau} - r)D_j/S_j$$

where i_j is the expected rate of return on capital stock of a debted firm, r is the interest rate, D_j is the market value of the debts of the jth firm, and S_j is the market value of its common shares. The hypothetical model formulation assumes that market debt value and book debt value are equal.

Equation A914 is an equivalent formulation for the first equation and equation A918 and A919 are equivalent formulations for the second equation presented above from the work of Modigliani and Miller (21).

Equation A921 defines the debt input indicator (DII) to be equal to one if the interest rate (IR) is equal to or greater than the interest rate cut-off level (IRCO); otherwise, it is defined as equal to zero. The indicator, therefore, is zero only when the interest rate is less than the cut-off value.

51A DII.K=CLIP(1,0,IR.K,IRCO) (A921)

Equation A923 defines the minimum net profit indicator for debt (MNPID) to be equal to zero if the average net profit rate (ANPR) is equal to the minimum net profit rate for debt (MNPRD); otherwise, it is defined as equal to one. Therefore, MNPID can equal zero only when the average net profit rate (ANPR) equals or exceeds the minimum profit rate for debt (MNPRD).

51A MNPID.K=CLIP(0,1,ANPR.K,MNPRD) (A923)

Equation A925 defines the debt capital acquisition indicator (DCAI) to be equal to the sum of the debt input indicator (DII) and the minimum net profit indicator for debt (MNPID).

7A DCAI.K=DII.K+MNPID.K (A925)

Equation A926 defines the debt fund addition (DFA) to be equal to the debt fund increment (FI) if the debt capital acquisition indicator is equal to zero; otherwise, it is defined as equal to zero.

49A DFA.K=SWITCH(DFI,0,DCAI.K) (A926)

Equation A928 defines the funds available for investment (FAI) to be equal to the difference between the cash level (CASH) and the minimum cash balance (MCB).

7A FAI.K=CASH.K-MCB (A928)

Equation A930 defines the debt principal payment rate (DPPR) to be equal to the funded debt level (FDL) divided by the number of debt payments (NDP).

20A DPPR.K=FDL.K/NDP.K (A930)

Equation A931 defines the number of debt payments (NDP) to be equal to the product of the years of debt payment (YODP) and 52.

12A NDP.K=(YODP)(52) (A931)

Equation A933 defines the funded debt level (FDL) at time K to be equal to the funded debt level at time J plus the difference between the debt capital input rate (DCIR) and the debt principal payment rate (DPPR). The equation for DCIR is located in the policy variables sector.

1L FDL.K=FDL.J+(DT)(DCIR.J.-DPPR.J) (A953)

Equation A934 defines the net profit after taxes (NPAT) to be equal to the difference between the net profit rate before taxes (GPR) and the tax rate used (TRU).

7A NPAT.K=GPR.K-TRU.K (A934)

Equation A935 defines the profit to date (PTD) at time K to be equal to the profit to date at time J plus the net profit after taxes (NPAT) during interval JK.

1L PTD.K=PTD.J+(DT)(NPAT.J+0) (A935)

Equation A936 defines the average net profit rate (ANPR) at time K to be equal to the average net profit rate at time J plus the difference between the net profit after taxes rate (NPATR) and the average net profit rate (ANPR) divided by the time to average the net profit rate (TANPR).

3L ANPR.K=ANPR.J+(DT)(1/TANPR)(NPATR.J-ANPR.J) (A936)

Equation A938 defines the net profit after taxes rate (NPATR) to be equal to the product of the net profit after taxes (NPAT) and 52 divided by the market net worth (MNW).

44A NPATR.K=(NPAT.K)(52)/MNW.K (A938)

Equation A939 defines the profit before taxes (GP) to be equal to the product of 52 and the profit before taxes rate (GPR).

12A GP.K=(52)(GPR.K) (A939)

Equation A940 defines the profit before taxes (GPR) to be equal to the sales input rate (SIR) less the interest expense rate (IER), the general and administrative expense rate (GAER), the overhead cost rate (OCR), the material cost rate (MCR), the professional labor cost rate (PLCR), the factory labor cost rate (FLCR), and the bad debts expense rate (BDER).

11A GPR.K=SIR.K-IER.K-GAER.K-OCR.K-MCR.K-PLCR.K-FLCR.K-BDER.K (A940)

Equation A941 defines the sales input rate (SIR) to be equal to the product of the product price (PP) and the order input rate (OIR).

12A SIR.K=(OIR.JK)(PP) (A941)

Equation A943 defines the additional profits before taxes (AGP) to be equal to the difference between the profits before taxes (GP) and $25,000.

7A AGP.K=GP.K-25000 (A943)

Equation A944 defines the total assets (TA) to be equal to the sum of the current assets (CA) and the fixed assets (FA).

7A TA.K=CA.K+FA.K (A944)

Equation A945 defines the current assets (CA) to be equal to the sum of the cash level (CASH), the total inventory (TI), and the accounts receivable (AR), less the reserve for bad debts (RFBD).

9A CA.K=CASH.K+TI.K+AR.K-RFBD.K (A945)

Equation A946 defines the reserve for bad debts (RFBD) to be equal to the product of the bad debts percentage (BDP) and the accounts receivable (AR).

12A RFBD.K=(BDP)(AR.K) (A946)

Equation A947 defines the bad debts expense rate (BDER) to be equal to the product of the bad debts percentage (BDP) and the accounts receivable input rate (ARIR).

12A BDER.K=(BDP)(AIR JK) (A947)

Equation A949 defines the fixed assets (FA) to be equal to the sum of the net equipment book value (NEBV), the land (LAND), and the building cost value (BCV), less the reserve for building depreciation (RFBDP).

9A FA.K=NEBV.K+BCV-RFBDP.K+LAND (A949)

Equation A950 defines the current liabilities (CL) to be equal to the accounts payable (AP).

6A CL.K=AP.K (A950)

Equation A951 defines the fixed liabilities (FL) to be equal to the funded debt level (FDL).

6A FL.K=FDL.K (A951)

Equation A952 defines the total liabilities to be equal to the sum of the current liabilities (CL) and the fixed liabilities (FL).

7A T.K=CL.K+FL.K (A952)

Equation A953 defines the book net worth (NW) to be equal to the difference between the total assets (TA) and the total liabilities (TL).

7A NW.K=TA.K-TL.K (A953)

Asset and Liability Levels Sector

This sector was formulated to provide a continuous accounting of all asset and liability levels to provide a means for determination of book net worth. Asset levels considered include equipment book value, inventory book value, net book accounts receivable, accounts payable, net book building value, land value and book funded debt. Figure 13, a flow diagram of the asset and liability levels sector of Model A, graphically indicates the interconnections between these variables.

Equation A954 defines the total inventory (TI) to be equal to the sum of the material in stock inventory (MISI), the material in process one, two and three inventory (MIP1, MIP2 and MIP3), and final product awaiting shipment inventory (FPASI).

10A TI.K=MISI.K+MIP1I.K+MIP2I.K+MIP3I.K+FPASI.K+0 (A954)

Equation A955 defines the material in stock inventory (MISI) to be equal to the product of the material in stock (MIS) and the material purchase price (MPP).

12A MISI.K=(MIS.K)(MPP) (A955)

Equation A956 defines the material in process one inventory (MIP1I) to be equal to the product of the material in process one (MIP1) and the market value of process one material (MV1).

12A MIP1I.K=(MIP1.K)(MV1.K) (A956)

Equations A957 and A958 are formulations similar to equation A956

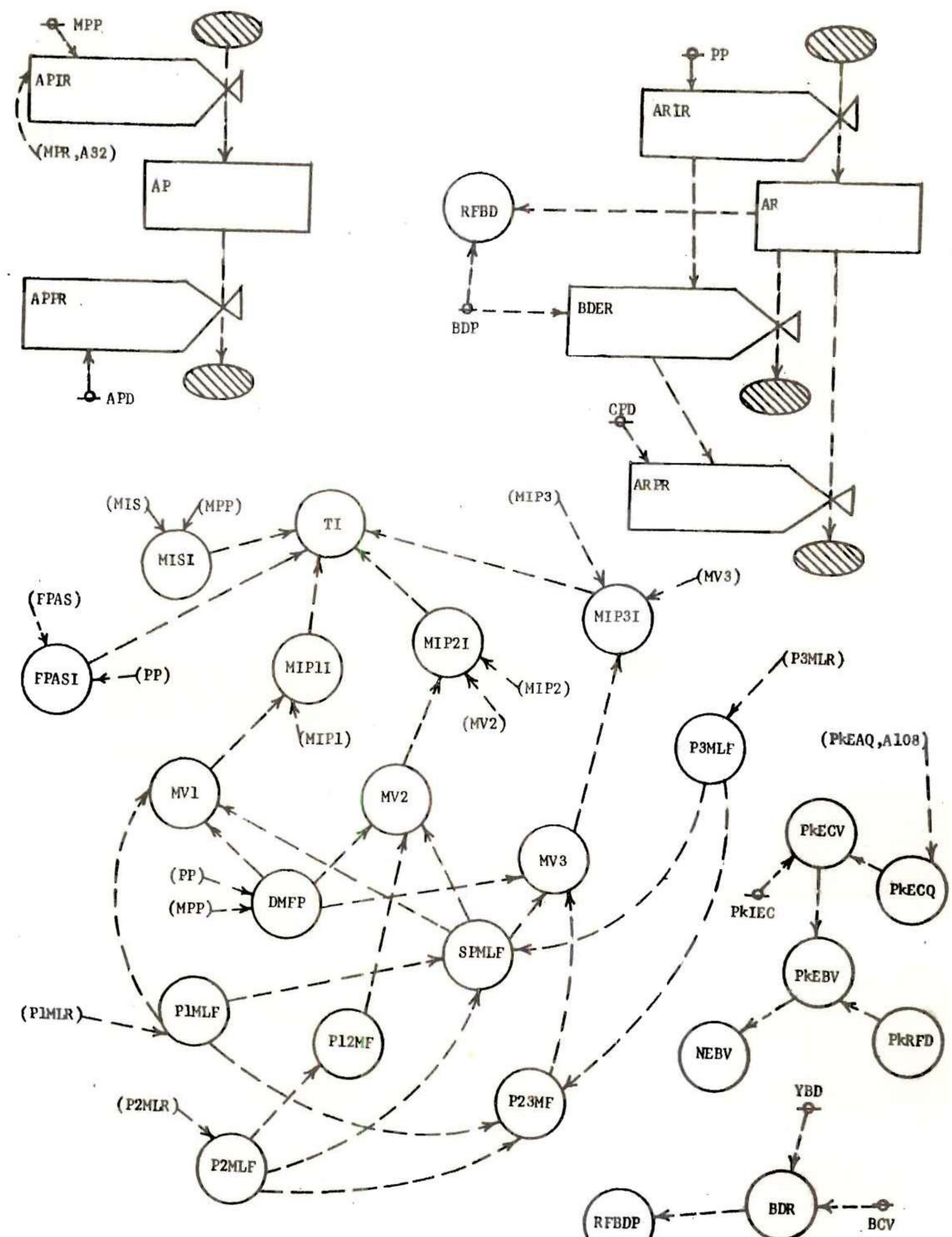


Figure 13. A Flow Diagram of the Asset and Liability Levels Sector of Model A

for processes two and three, respectively.

Equation A959 defines the final product awaiting shipment inventory (FPASI) to be equal to the product of the final product awaiting shipment (FPAS) and the purchase price (PP).

12A FPASI.K=(FPAS.K)(PP) (A959)

Equation A960 defines the process one material to labor factor (P1MLF) to be equal to the reciprocal of the process one material to labor ratio (P1MLR).

20A P1MLF.K=1/P1MLR (A960)

Equations A961 and A962 are formulations similar to equation A960 for processes two and three, respectively.

Equation A963 defines the sum of the process material to labor factors (SPMLF) to be equal to the sum of the process material to labor factors (P1MLF, P2MLF and P3MLF) for each process.

8A SPMLF.K=P1MLF.K+P2MLF.K+P3MLF.K (A963)

Equation A964 defines the difference between the material and final product price (DMFP) to be equal to the difference between the product price (PP) and the material purchase price (MPP).

7A DMFP.K=PP-MPP (A964)

Equation A965 defines the market value of process one material (MV1) to be equal to the product of the process one material to labor factor (P1MLF), one-half, and the difference between the material and final product price (DMFP), divided by the sum of the process material to labor factors (SPMLF).

46A MV1.K=(P1MLF.K)(.5)(DMFP.K)/((SPMLF.K)(1)(1)) (A965)

Equation A966 defines the process one and two material factor (P12MF) to be equal to the sum of the process one material to labor factor (P1MLF) and the product of one-half and the process two material to labor factor (P2MLF).

14A P12MF.K=P1MLF.K+(.5)(P2MLF.K) (A966)

Equation A967 defines the market value of process two material (MV2) to be equal to the product of the process one and two material factor (P12MF) and the difference between material and the final product price (DMFP), divided by the sum of the process material to labor factors (SPMLF).

44A MV2.K=(P12MF.K)(DMFP.K)/SPMLF.K (A967)

Equation A968 defines the process one, two and three material factor (P23MF) to be equal to the sum of the process one material to labor factor (P1MLF), the process two material to labor factor (P2MLF), and the product of one-half and the process three material to labor factor (P3MLF).

16A P23MF.K=(1)(P1MLF.K)+(1)(P2MLF.K)+(.5)(P3MLF.K)+(1)(0) (A968)

Equation A969 defines the market value of process three material (MV3) to be equal to the product of the process one, two and three material factor (P23MF) and the difference between the material and final product price (DMFP), divided by the sum of process material labor factors (SPMLF).

44A MV3.K=(P23MF.K)(DMFP.K)/SPMLF.K (A969)

Equations A954 to A969 inclusive are a formulation for summing the value of materials in stock, materials in process, and final product awaiting shipment. The market value for materials in process is based on the assumption that each unit has received half of the labor used in a process if in that process at time of inventory and that in-process labor value is directly related to the labor content of processes one, two and three, respectively.

Equation A970 defines the net equipment book value (NEBV) to be equal to the sum of the process equipment book values (P1EBV, P2EBV and P3EBV).

8A NEBV.K=P1EBV.K+P2EBV.K+P3EBV.K (A970)

Equation A971 defines the process one equipment book value (P1EBV) to be equal to the difference between the process on equipment cost value (P1ECV) and the process one reserve for depreciation (P1RFD).

7A P1EBV.K=P1ECV.K-P1RFD.K (A971)

Equation A972 defines the process one equipment cost value (P1ECV) to be equal to the product of the process one initial equipment cost (P1IEC) and the process one equipment cost quantity (P1ECQ).

12A P1ECV.K=(P1IEC)(P1ECQ.K) (A972)

Equation A973 defines the process one equipment cost quantity (P1ECQ) at time K to be equal to the equipment cost quantity at time J plus the process one equipment acquisition quantity (P1EAQ) during interval JK.

1L P1ECQ.K=P1ECQ.J+(DT)(P1EAQ.JK+0) (A973)

Equations A975 to A982 inclusive are formulations similar for processes two and three to equations A971 to A974 inclusive.

Equation A986 defines the building depreciation rate (BDR) to be equal to the building cost value (BCV) divided by the product of the years of building depreciation (YBD) and 52.

42A BDR.K=BCV/(YBD)(52) (A986)

Equation A989 defines the reserve for building depreciation (RFBDP) at time K to be equal to the reserve for building depreciation at time J plus the building depreciation rate (BDR) during interval JK.

1L RFBDP.K=RFBDP.J+(DT)(BDR.J+0) (A989)

Equation A991 defines the accounts payable (AP) at time K to be equal to the accounts payable at time J plus the difference between the accounts payable input rate (APIR) and the accounts payable payment rate (APPR) during interval JK.

1L AP.K=AP.J+(DT)(APIR.JK-APPR.J) (A991)

Equation A992 defines the accounts payable payment rate (APPR) to be equal to the product of the material purchase rate (MPR) and the material purchase price (MPP).

12A APIR.K=(MPR.K)(MPP) (A994)

Equation A996 defines the accounts receivable (AR) at time K to be equal to the accounts receivable at time J plus the difference between the accounts receivable input rate (ARIR) and the sum of the bad debts expense rate (BDER) and the accounts receivable payment rate (ARPR) during interval JK.

52L AR.K=AR.J+(DT)(ARIR.JK-BDER.J-ARPR.J+0) (A996)

Equation A997 defines the accounts receivable input rate (ARIR) to be equal to the product of the shipping rate (SR) and product price (PP).

12R ARIR.KL=(SR.JK)(PP) (A997)

Equations A998 to A1087 represent initial value assignments for level equations and a complete listing appears in Appendix A.

Policy Variables and Constants Sector

Equations in this sector were removed from the sectors in which they would logically have been located and grouped in this sector in order to concentrate into one group all equations for which revised policies would be employed. All previous sectors will remain unchanged through the research, whereas all revised policy changes will be made relative to equations and constants in this sector.

The following formulation is for the assumed existing policies.

Equation A1088 defines the process one equipment depreciation (P1ED) to be equal to the sum of the process one initial equipment depreciation (P1IED) and the process one acquired equipment depreciation (P1AED).

7A P1ED.K=P1IED.K+P1AED.K (A1088)

Equation A1091 defines the debt capital input rate (DCIR) to be equal to the debt fund addition (DFA) if the debt fund increment (DFI) is equal to or greater than the funds available for investment (FAI); otherwise, it is defined as equal to zero.

51A DCIR.K=CLIP(DFA.K,0,DFI,FAI.K) (A1091)

Equation A1092 defines the minimum reliability signal for process one machine one (MR11S) to be equal to zero if the acceptable reliability indicator for process one machine one (ARI11) is equal to or greater than the process one machine one reliability (P11R); otherwise, it is defined as equal to one.

51A MR11S.K=CLIP(0,1,ARI11,P11R.K) (A1092)

Equation A1118, which required three data cards, specifies the variables to be printed in tabular form as output.

Equation A1119 specifies the variables to be plotted.

Equation A1120 specifies the length of the simulation interval, the length of the simulation in intervals, the frequency of printed output in increments of DT intervals, and the frequency of plotting in increments of DT intervals.

CHAPTER III

THE ABC COMPANY GROWTH MODEL

A General Description of the Model

The objective in developing the ABC Company growth model was to develop a growth model for a specific company and compare some portion of its actual past growth with a simulation of past growth. Since correspondence between actual and simulated growth was desired, an attempt was made to determine appropriate values for parameters and coefficients employed in the model. Many of the constants and coefficients were derived by multiple regression analyses of company data. Regression analyses were made by employing a Burroughs Corporation program developed by Mr. Charles L. Clark (2). Regression analyses were run on the B5500 computer at the Rich Electronic Computer Center of the Georgia Institute of Technology.

The ABC Company growth model is a model for an actual company. Since this model employs proprietary financial information for five years of operation of the company, a concerted effort was made to code product, equipment and other identifying information, as requested by the company president. Description of the company, therefore, will be brief.

The ABC Company is a small manufacturing firm producing six product lines. Each product is produced by employing some successive combination of as many as three of five readily identifiable cost centers which possess multiples of similar equipment. The company produces only a very small portion of the national demand for its products, and therefore, a change in its output over a short period of years would not have a significant effect on product prices.

Figure 14 is a simplified flow diagram of Model B indicating the major intersectoral relationships. Appendices C, D and E are respectively, a Model B computer program listing, a glossary for variables and constants employed in Model B, and a summary of information obtained from the ABC Company.

Simulation Model Sectors

Model B contains seven sectors: namely, the sales input sector, the machine and labor loading sector, the cost of goods manufactured sector, the operating cost sector, the equipment status sector, the labor status sector, and the fixed assets sector.

The sales input sector develops a product sales input for six product lines on the basis of regression relationships determined for sales during the period of interest. As in Model A, no attempt was made to develop relationships for variables external to the firm. Therefore, sales based on regression relationships provide the input to the model.

The machine and labor loading sector is a formulation for comparing labor and equipment capacity with demands for equipment and labor as dictated by the sales input. When a specific type of equipment or labor is required, the machine and labor loading sector triggers the equipment and labor status sectors to attempt to increase capacity to meet demands.

The labor status sector and the equipment status sector are formulated to represent company policies concerning the hiring of labor, the acquisition of equipment, and retirement relationships as well.

The cost of goods manufactured sector models the cost of goods

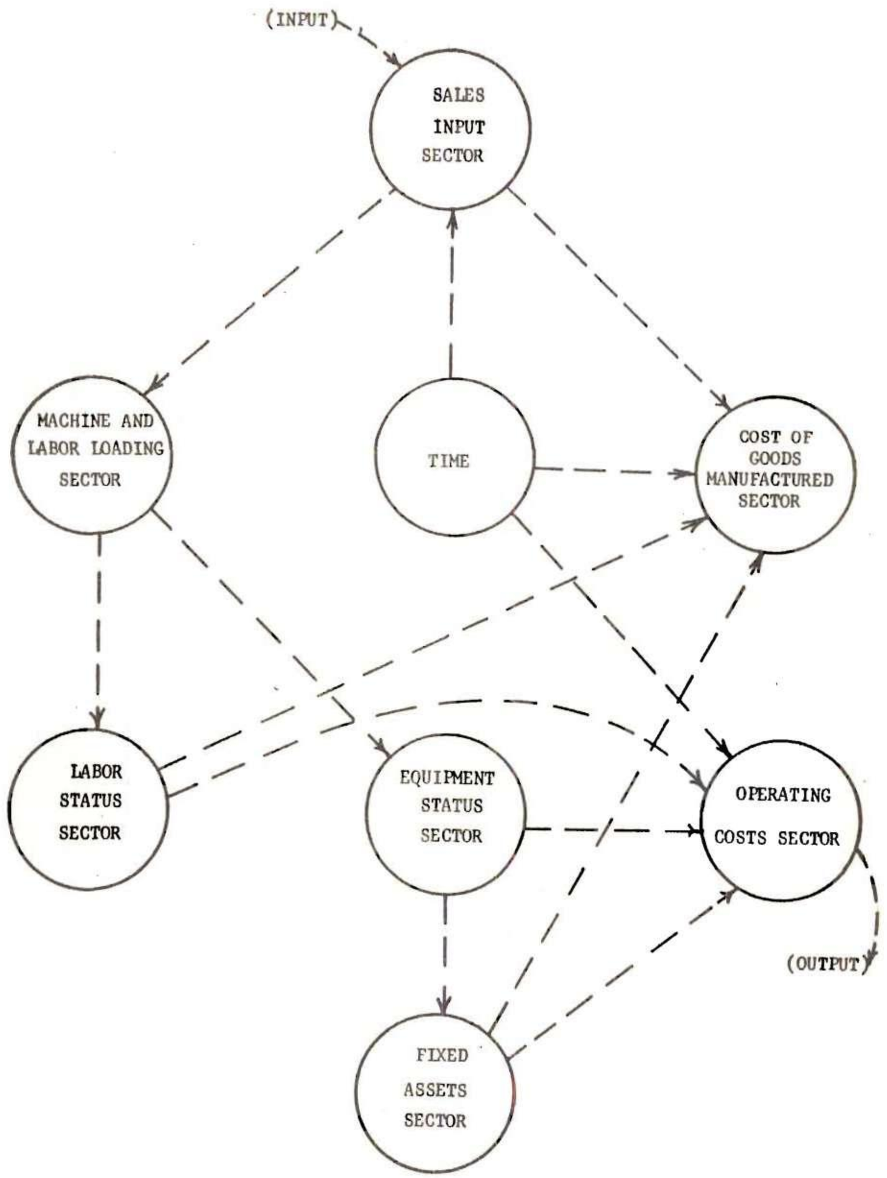


Figure 14. A Simplified Flow Diagram of Model B

manufactured statements for the company. The expense and income relationships are based on regression relationships with other primary variables in the model, such as sales of a particular product or the number of factory employees. The operating costs sector models the profit and loss statements of the company in a similar manner to that employed for the cost of goods manufactured sector.

The fixed assets sector was necessary to provide an input for major fixed asset changes for which a clearly defined policy was not apparent. Since this model was concerned only with simulating profit generating capability of the total operation, fixed asset inputs were employed only to serve as a basis for estimation of some expenses which are mainly a function of specific fixed asset levels. The following is a detailed description of the model, one sector at a time.

Sales Input Sector

Since a high correspondence between the model and the ABC Company information was desired, it was decided to use as sales input a piecewise linear regression of particular product sales against time for the five-year (i.e., 60-month) simulation period. Therefore, the sales input equations for this model possess linear regression constants and coefficients, and sales are a function of time. Since the ABC Company sold products classified into six product areas, the model contains a sales input for products coded as L, P, H and S, as well as purchased products (R) and miscellaneous products (M). Total manufactured products (TMS) is the sum of all products except purchased products. Figure 15 is a flow diagram of the sales input sector of model B.

Equation B1 defines L sales (LS) to be equal to constant A for L

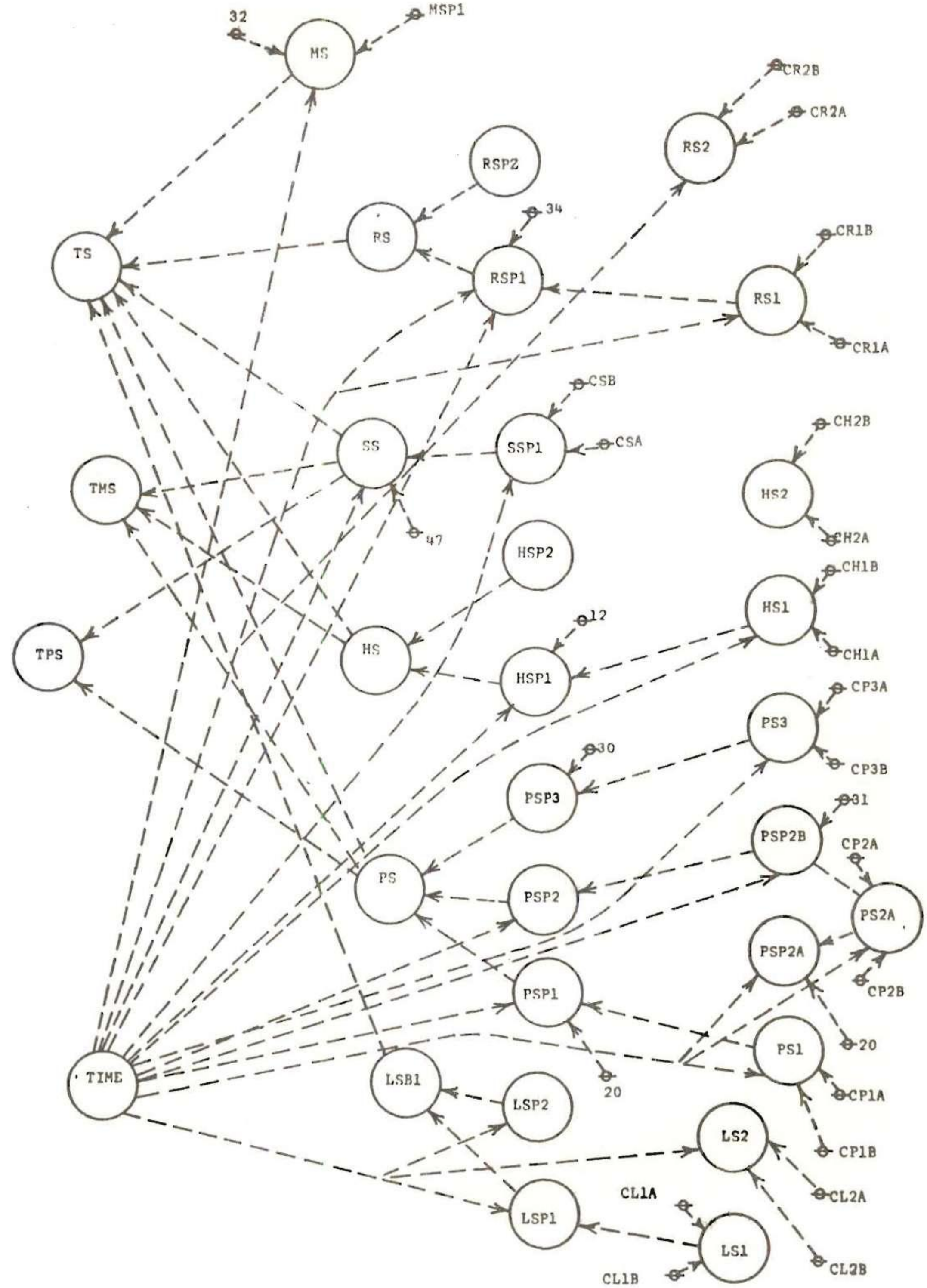


Figure 15. A Flow Diagram of the Sales Input Sector of Model B

sales (CLA) plus the product of constant B for L sales (CLB) and time (TIME)

14A LS.K=CLA+(CLB)(TIME.K) (B1)

Equation B4 defines P sales (PS) to be equal to the sum of P sales for period one (PSP1), P sales for period two (PSP2) and P sales for period three (PSP3).

8A PS.K=PSP1.K+PSP2.K+PSP3.K (B4)

Figure 16, for example, is a graph of actual P sales for the 60-month simulation period. Since sales reached a maximum during the second year, declined considerably in the third year, and then recovered gradually in the fourth and fifth years, it was decided to perform piecewise linear regression for the five-year period. Therefore, the first 18 months were designated as period one, the next 12 months as period two, and the remaining months as period three, as indicated in Figure 16.

Equation B5 defines P sales for period one (PSP1) to be equal to zero if time (TIME) is equal to or greater than 19; otherwise, it is defined as equal to P sales during period one (PS1). Therefore, the only time when PSP1 takes on a value other than zero is when TIME is less than 19.

51A PSP1.K=CLIP(0,PS1.K,TIME.K,19) (B5)

Equation B6 defines P sales during period one (PS1) to be equal to constant A for P sales during period one (CP1A) plus the product of constant B for P sales during period one (CP1B) and time (TIME).

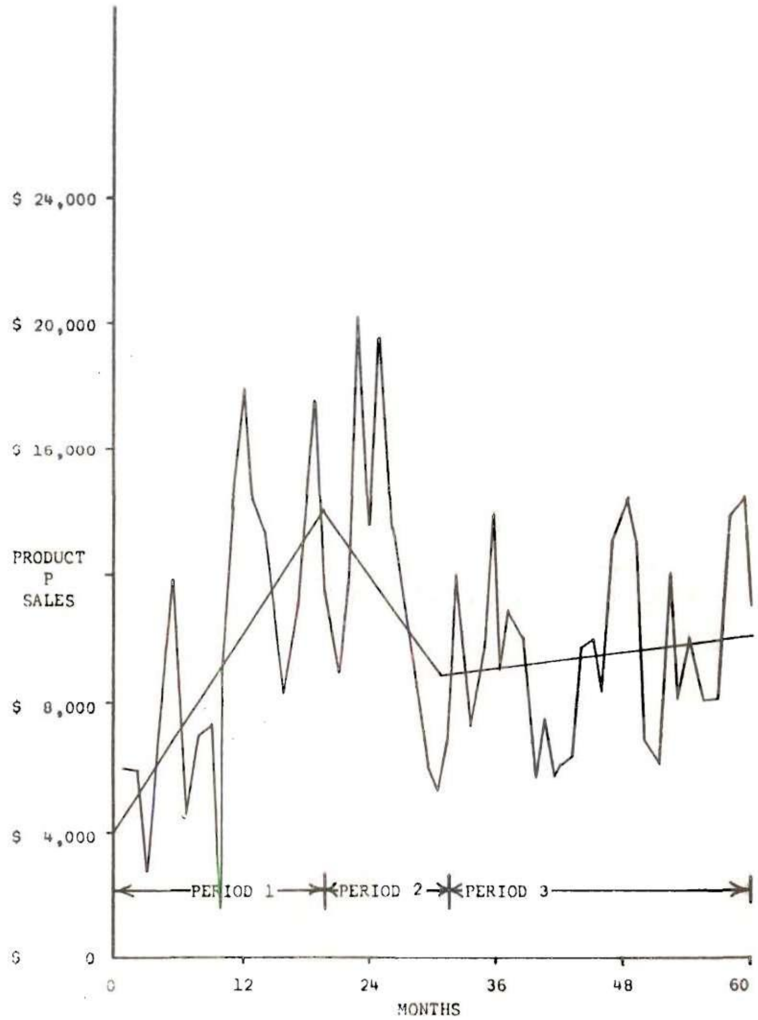


Figure 16. Actual Product P Sales by Months

14A PS1.K=CP1A+(CP1B)(TIME.K) (B6)

Equation B9 defines P sales for period three (PSP3) to be equal to P sales during period three (PS3) if time (TIME) is equal to or greater than 31; otherwise, it is defined as equal to zero. Therefore, the only time when PSP3 takes on a value other than zero is when TIME is equal to or greater than 31.

51A PSP3.K=CLIP(PS3.K,0,TIME.K,31) (B9)

Equation B10 defines P sales during period three (PS3) to be equal to constant A for P sales during period three (CP3A) plus the product of constant B for P sales during period three (CP3B) and time (TIME).

14A PS3.K=CP3A+(CP3B)(TIME.K) (B10)

Equation B13 defines P sales for period two (PSP2) to be equal to the difference between the P sales for period two amount A (PSP2A) and the P sales for period two amount B (PSP2B).

7A PSP2.K=PSP2A.K-PSP2B.K (B13)

Equation B14 defines P sales for period two amount A (PSP2A) to be equal to P sales during period two amount A (PS2A) if time (TIME) is equal to or greater than 19; otherwise, it is defined as equal to zero.

51A PSP2A.K=CLIP(PS2A.K,0,TIME.K,19) (B14)

Equation B15 defines P sales during period two amount A (PS2A) to be equal to constant A for P sales during period two (CP2A) plus the product of constant B for P sales during period two (CP2B) and time (TIME).

14A   PS2A.K=CP2A+(CP2B)(TIME.K)   (B15)

Equation B18 defines P sales during period two amount B (PSP2B) to be equal to P sales during period two amount A (PS2A) if time (TIME) is equal to or greater than 31; otherwise, it is defined as equal to zero. Therefore, when time is within period two, PSP2B is zero; however, when time is beyond, PSP2A causes PSP2 to equal zero.

51A   PSP2B.K=CLIP(PS2A.K,0,TIME.K,31)   (B18)

Equation B19 defines H sales (HS) to be equal to constant A for H sales (CHA) plus the product of constant B for H sales (CHB) and time (TIME).

14A   HS.K=CHA+(CHB)(TIME.K)   (B19)

Equation B22 defines S sales (SS) to be equal to S sales during period one (SSP1) if time (TIME) is equal to or greater than 47; otherwise, it is defined as equal to zero.

51A   SS.K=CLIP(SSP1.K,0,TIME.K,47)   (B22)

Equation B23 defines S sales during period one (SSP1) to be equal to constant A for S sales (CSA) plus the product of constant B for S sales (CSB) and time (TIME).

14A   SSP1.K=CSA+(CSB)(TIME.K)   (B23)

Equation B26 defines purchased product sales (RS) to be equal to the sum of purchased product period one sales (RSP1) and purchased product period two sales (RSP2).

14A SSP1.K=CSA+(CSB)(TIME.K) (B23)

Equation B27 defines purchased product period one sales (RSP1) to be equal to zero if time (TIME) is equal to or greater than 34; otherwise, it is defined as equal to purchased product sales during period one (RS1).

51A RSP1.K=CLIP(0,RS1.K,TIME.K,34) (B27)

Equation B28 defines purchased product sales during period one (RS1) to be equal to constant A for purchased product during period one (CR1A) plus the product of constant B for purchased product during period one (CR1B) and time (TIME).

14A RS1.K=CR1A+(CR1B)(TIME.K) (B28)

Equation B31 defines purchased product period two sales (RSP2) to be equal to purchased product sales during period two (RS2) if time (TIME) is equal to or greater than 34; otherwise, it is defined as equal to zero.

51A RSP2.K=CLIP(RS2.K,0,TIME.K,34) (B31)

Equation B32 defines purchased product sales during period two (RS2) to be equal to constant A for purchased product during period two (CR2A) plus the product of constant B for purchased product during period two (CR2B) and time (TIME).

14A RS2.K=CR2A+(CR2B)(TIME.K) (B32)

Equation B35 defines miscellaneous sales (MS) to be equal to miscellaneous sales during period one (MSP1) if time (TIME) is equal to or greater than 32; otherwise, it is defined as equal to zero. Miscellaneous sales began in the 32nd month of the 50-month simulation period.

51A MS.K=CLIP(MSP1,0,TIME.K,32) (B35)

Since miscellaneous sales were of nominal value and erratic in nature, their average value of $457 was employed in the model.

Equation B37 defines total sales (TS) to be equal to the sum of L sales (LS), P sales (PS), H sales (HS), S sales (SS), purchased products sales (RS), and miscellaneous sales (MS).

10A TS.K=LS.K+PS.K+HS.K+SS.K+RS.K+MS.K (B37)

Equation B38 defines total manufactured sales (TMS) to be equal to the sum of L sales (LS), P sales (PS), H sales (HS), S sales (SS) and miscellaneous sales (MS).

10A TMS.K=LS.K+PS.K+HS.K+SS.K+MS.K+0 (B38)

Equation B39 defines total P and S sales (TPS) to be equal to the sum of P sales (PS) and S sales (SS0.

7A TPS.K=PS.K+SS.K (B39)

Machine and Labor Loading Sector

The manufacturing process for the ABC Company involved six distinct major equipment types. These equipment groups were coded as machines C, T, H, U, P and V. Table 1 indicates the equipment employed in the manufacture of each product group. Figure 17 is a flow diagram indicating the interconnections between all variables of the machine and

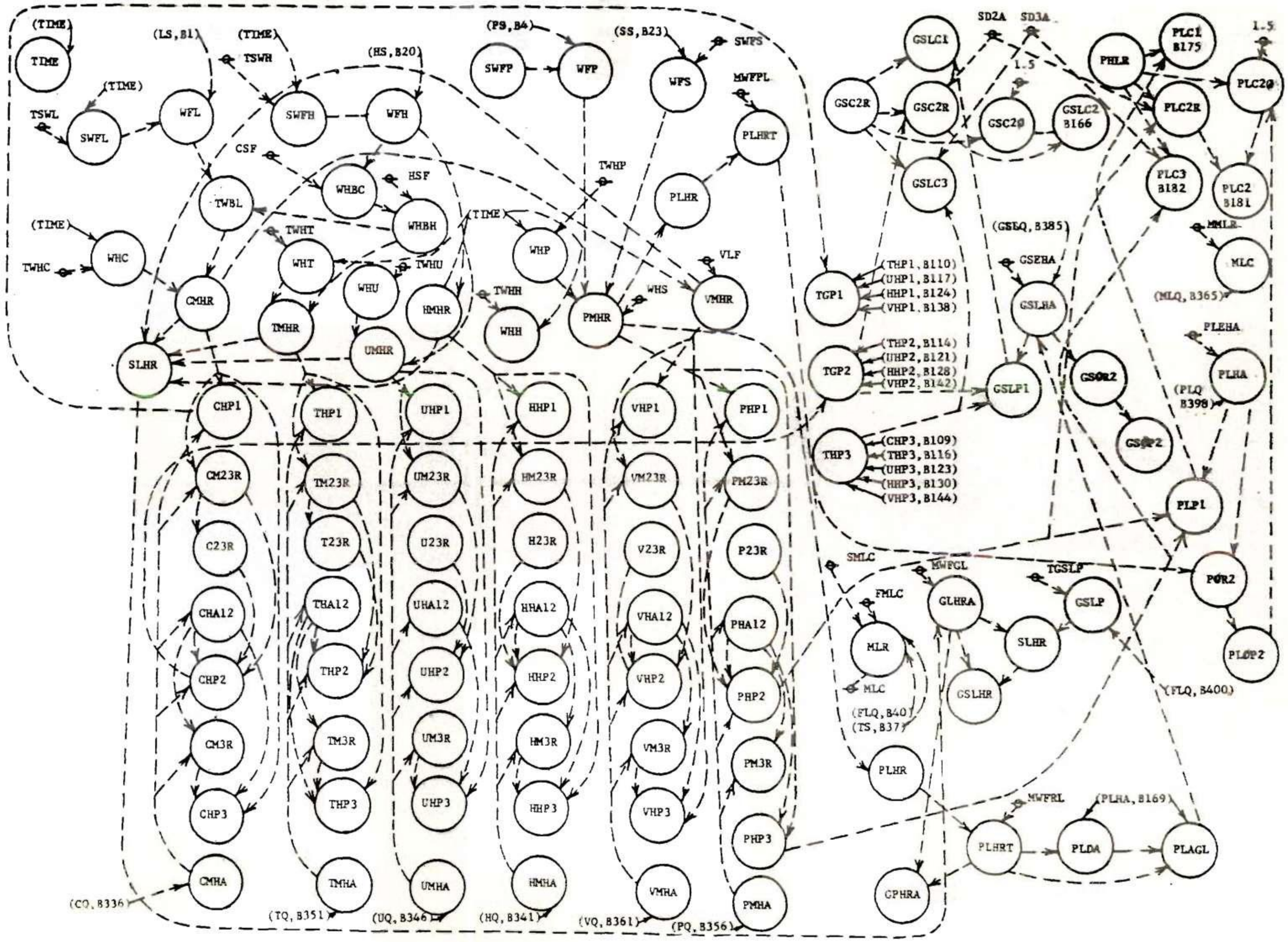


Figure 17. A Flow Diagram of the Machine and Labor Loading Sector of Model B

labor loading sector of Model B.

At the beginning of the simulation period, the initial quantity of units for specific equipment types was set equal to the actual number of machines in use at that time. By determing a weight to sales ratio from sampled job orders for each product type at different periods of time

Table 1. Major Equipment Types Employed on Product Groups

Product Group	Major Equipment Types Employed
L	C, T, V
P	P
H	C, T, H, U
S	P
R	NONE
M	NONE

during the 60-month period, an estimate of product weight sold per month was obtained. By sampling specific job orders for machine times charged for specific product groups, it was possible to estimate machine time to product weight ratios. Therefore, a means for estimating equipment hours required as a function of sales dollars was developed. The machine hours required for specific equipment types determined both the need for additional processing equipment and the need for factory labor to man process equipment.

In this model, a distinction is made between overtime and straight-time hours, and consideration is given to second and third-shift pay differentials for second and third-shift factory and service labor. When sufficient equipment units are available, the sales input creates a demand for trained labor which, if available, is added on the first shift. If available equipment is insufficient to meet the demand for machine hours created by sales, then second and third-shift labor is preferable to overtime labor, if sufficient additional labor is available. The formulation was developed in this manner to allow consideration of alternate policies relative to equipment acquisition and overtime.

Equation B40 defines weight of final product L (WFL) to be equal to the product of the sales to weight factor for product L (SWFL) and L sales (LS).

```
12A     WFL.K=(SWFL.K)(LS.K)                                        (B40)
```

Equation B41 defines the sales to weight factor for product L (SWFL) to be a table function of time (TIME), starting with one month and ending with 61 months in increments of six months. Equation B42 assigns table values to the sales to weight factor for product L (SWFL) corresponding to the above incremental values of time (TIME).

```
58A     SWFL.K=TABHL(TSWL,TIME.K,1,61,6)                            (B41)
C       TSWL*=3.03/3.08/2.94/3.62/3.06/3.59/3.46/3.07/3.38/
              3.14/3.40                                             (B42)
```

The constant values employed in equation B42 were derived from ABC Company information.

Equations B43 to B45 inclusive provide a formulation for product H similar to that developed for product L in equations B40 to B42 inclusive.

Equation B46 defines weight of product H before machine H (WHBH) to be equal to weight of product H before machine C (WHBC) divided by the machine H salvage factor (HSF).

20A WHBH.K=WHBC.K/HSF (B46)

Appropriate salvage values for all machines were estimated by the shop foreman of the ABC Company. Equation B47 and other scrap value assignment equations were assigned values according to these estimates.

Equation B48 defines the total weight of product L manufactured (TWLM) to be equal to the sum of the weight of final product L (WFL) and the weight of product H before machine H (WHBH).

7A TWLM.K=WFL.K+WHBH.K (B48)

Equation B49 defines the total weight of beginning product L material (TWBL) to be equal to the total weight of product L manufactured (TWLM) divided by the machine T salvage factor (TSF).

20A TWBL.K=TWLM.K/TSF (B49)

Equations B51 to B55 are a formulation for products P and S for estimating the weight of product sold similar to that formulated for product L in equations B40 to B42 inclusive.

Equation B56 defines machine C hours required (CMHR) to be equal to the product of the weight to hours factor for machine C (WHC) and the total weight of beginning product L material (TWBL).

12 CMHR.K=(WHC.K)(TWBL.K) (B56)

Equation B57 defines the weight to hours factor for machine C (WHC) to be a table function of time (TIME), starting with six and ending with 54 in increments of 12. Equation B58 assigns table values to the weight to hours factor for machine C (WHC) corresponding to the above incremental values of time (TIME).

58A WHC.K=TABHL(TWHC,TIME.K,6,54,12) (B57)

C TWHC*=0.00521/0.00399/0.00277/0.00224/0.00171 (B58)

The first, third and fifth year values above were estimated by averaging a sample of job orders for each year. Second and fourth year values represent linear interpolations with respect to the other years.

Equation B59 defines the machine P hours required (PMHR) to be equal to the product of the weight to hours factor for machine P (WHP) and the weight of final product P (WFP) plus the product of the weight to hours factor for product S on machine P (WHS) and the weight of final product S (WFS).

15A PMHR.K=(WHP.K)(WFP.K)+(WHS)(WFS.K) (B59)

Equations B60 to B62 inclusive are a formulation for machine P similar to equations B57 and B58 for machine C.

Equation B63 defines the machine T hours required (TMHR) to be equal to the product of the weight to hours factor for machine T (WHT), the total weight of product L manufactured (TWLM) and the manufactured product adjustment factor (MAF). Since some customers purchase product L that has not been processed by machine T, the manufactured product adjustment factor (MAF) is employed to reduce the requirement for machine T accordingly. The shop foreman estimated that approximately 25 per cent of product L does not require machine T processing; therefore, the manufactured product adjustment factor (MAF) was set equal to 0.75.

13A TMHR.K=WHT.K)(TWLM.K)(MAF) (B63)

Equations B63 to B66, B67 to B71, and B72 to B74 represent formulations, respectively, for machines T, H and U, that are similar to equations B56 to B58 for machine C.

Equation B75 defines the machine V hours required (VMHR) to be equal to the product of the machine V usage factor (VLF) and the machine C hours required (CMHR). Machine V usage is a constant percentage of machine C usage; it was estimated by the shop foreman to be approximately 20 per cent. Therefore, the machine V usage factor (VLF) was set equal to 0.20.

12A VMHR.K=(VLF)(CMHR.K) (B75)

Equation B77 defines the general labor hours required (GLHR) to be equal to the sum of the various machine requirements (CMHR,TMHR,UMHR,HMHR and VMHR).

10A GLHR.K=CMHR.K+TMHR.K+UMHR.K+HMHR.K+VMHR.K+0 (B77)

Equation B78 defines the general labor hours required actual (GLHRA) to be equal to the product of the general labor hours required (GLHR) and the miscellaneous work factor for general labor (MWFGL). The miscellaneous work factor was estimated by the shop foreman to be equal to 1.2.

12A GLHRA.K=(GLHR.K)(MWFGL) (B78)

Equation B80 defines the service labor hours required (SLHR) to be equal to the product of the general labor hours required actual (GLHRA) and the general to service labor percentage rate (GSLPR).

```
12A     SLHR.K=(GLHRA.K)(GSLPR.K)                                  (B80)
```

Equation B81 defines the general to service labor percentage rate (GSLPR) to be equal to the general to service labor percentage A (GSLPA) if time (TIME) is equal to or greater than 42; otherwise, it is defined as equal to the general to service labor percentage (GSLP).

```
51A     GSLPR.K=CLIP(GSLPA.K,GSLP.K,TIME.K,42)                     (B81)
```

In the 42nd month of the five-year period to be simulated, the ABC Company installed a facility for manufacturing one of its basic materials. This facility, therefore, caused a significant change in the percentage of service to machine labor. This required adjustment in the service to general labor ratio, and is reflected in the general to service labor percentage A (GSLPA).

Equation B82 defines the general to service labor percentage (GSLP) to be a table function of the general and service labor quantity (GSLQ), starting with 10 and ending with 40 in increments of five employees. Equation B83 assigns the shop foreman's estimate of table values to the general to service labor percentage (GSLP) corresponding to the above incremental values of the general and service labor quantity (GSLQ).

```
58A     GSLP.K=TABHL(TGSLP,GSLQ.K,10,40,5)                         (B82)
C       TGSLP*=0.20/0.33/0.40/0.40/0.40/0.40/0.40                  (B83)
```

Equations B84 and B85 are formulations similar to the above for the general to service labor percentage A (GSLPA).

Equation B86 defines the process labor hours required (PLHR) to be equal to the machine P hours required (PMHR).

6A PLHR.K=PMHR.K (B86)

Equation B87 defines the processing labor hours required in total (PLHRT) to be equal to the product of the miscellaneous work factor for process labor (MWFPL) and the process labor hours required (PLHR). The miscellaneous work factor for process labor (MWFPL) was estimated by the shop foreman to be equal to 1.10.

12A PLHRT.K=(MWFPL)(PLHR.K) (B87)

Equation B89 defines the general and process hours required (GPHRA) to be equal to the sum of the general labor hours required actual (GLHRA) and the process labor hours required in total (PLHRT).

7A GPHRA.K=GLHRA.K+PLHRT.K (B89)

Equation B90 defines the general and service labor hours required (GSLHR) to be equal to the sum of the general labor hours required actual (GLHRA) and the service labor hours required (SLHR).

7A GSLHR.K=GLHRA.K+SLHR.K (B90)

Equation B91 defines the machine C hours available (CMHA) to be equal to the product of the machine C quantity (CQ) and the machine C hours available per shift (CHAPS).

12A CMHA.K=(CQ.K)(CHAPS) (B91)

Equations B93, B95, B97, B99 and B101 are formulations similar to the above for machines H, U, T, P and V, respectively. Estimates of available machine hours were made by the shop foreman.

Equation B103 defines machine C hours payable on the first shift (CHP1) to be equal to the machine C hours available (CMHA) if the machine C hours required (CMHR) are equal to or greater than the machine C hours available (CMHA); otherwise it is defined as equal to the machine C hours required (CMHR).

51A CHP1.K=CLIP(CMHA.K,CMHR.K,CMHR.K,CMHA.K) (B103)

Equation B104 defines the machine C hours remaining for the second and third shift (CM23R) to be equal to the difference between the machine C hours required (CMHR) and the machine C hours available (CMHA).

7A CM23R.K=CMHR.K-CMHA.K (B104)

Equation B105 defines the machine C actual hours remaining for the second and third shift (C23R) to be equal to the machine C hours remaining for the second and third shift (CM23R), if the machine C hours remaining for the second and third shift (CM23R), are equal to or greater than zero; otherwise, it is defined as equal to zero. This equation limits consideration to a non-negative difference between required and available hours.

51A C23R.K=CLIP(CM23R.K,0,CM23R.K,0) (B105)

Equation B106 defines the machine C hours available for the first and second shift (CHA12) to be equal to twice the machine C hours available (CMHA).

12A CHA12.K=(2)(CMHA.K) (B106)

Equation B107 defines the machine C hours payable on the second shift (CHP2) to be equal to the machine C hours available (CMHA), if the machine C hours remaining for the second and third shift (CM23R) are equal to or greater than the machine C hours available (CMHA); otherwise, it is defined as equal to the machine C actual hours remaining for the second and third shift (C23R).

51A CHP2.K=CLIP(CMHA.K,C23R.K,CM23R.KCMHA.K) (B107)

Equation B108 defines the machine C hours remaining for the third shift (CM3R.K) to be equal to the difference between the machine C hours required (CMHR) and the machine C hours available for the first and second shift (CHA12).

7A CM3R.K=CMHR.K-CHA12.K (B108)

Equation B109 defines the machine C hours payable on the third shift (CHP3) to be equal to the machine C hours required for the third shift (CM3R) if the machine C hours required (CMHR) are equal to or greater than the machine C hours available on the first and second shift (CHA12); otherwise, it is defined as equal to zero.

51A CHP3.K=CLIP(CM3R.K,0,CMHR.K,CHA12.K) (B109)

In the above formulations, expressed by equations B104 to B109 inclusive, the number of existing machine units determines the available machine hours per shift for a given machine type. If the first-shift availability is insufficient to handle the required machine hours, additional machine work is performed on the second shift. If the first and second-shift capacity for a machine type is insufficient to handle required machine hours, a third shift is utilized to complete work remaining after completely utilizing available first and second-shift capacity.

Equations B110 to B144 inclusive are formulations similar to the above for machine types T, U, H, P and V.

Equation B145 defines the total general labor hours payable on the first shift (TGP1) to be equal to the sum of the various general machine type hours payable on the first shift (CHP1, THP1, UHP1, HHP1, VHP1).

10A TGP1.K=CHP1.K+THP1.K+UHP1.K+HHP1.K+VHP1.K+0 (B145)

Equations B146 and B147 are formulations similar to the above for shifts two and three.

Equation B148 defines the general and service labor hours available (GSLHA) to be equal to the product of the general and service labor effective hours available (GSEHA) and the general and service labor quantity (GSLQ) plus the process labor available for general labor (PLAGL). General and service labor effective hours available (GSEHA) were estimated by the shop foreman to be equal to 160 hours per month.

15A GSLHA.K=(GSEHA)(GSLQ.K)+(PLAGL.K)(1) (B148)

Equation B150 defines the process labor available for general labor (PLAGL) to be equal to the process labor difference available (PLDA) if the process labor hours available (PLHA) are equal to or greater than the process labor hours required in total (PLHRT); otherwise, it is defined as equal to zero.

51A PLAGL.K=CLIP(PLDA.K,0,PLHA.K,PLHRT.K) (B150)

Equation B151 defines the process labor difference available (PLDA) to be equal to the difference between the process labor hours available (PLHA) and the process labor hours required in total (PLHRT).

7A PLDA.K=PLHA.K-PLHRT.K (B151)

Equation B152 defines the general and service labor effective hours (GSLEH) to be equal to the product of the general and service effective hours available (GSEHA) and the effective general and service labor (EGSL) plus the process labor available for general labor (PLAGL).

15A GSLEH.K=(GSEHA)(EGSL.K)+(PLAGL.K)(1) (B152)

Equation B153 defines general and service labor hours payable on the first shift (GSLP1) to be equal to the general service labor hours available (GSLHA) less the total general labor hours payable on the second shift (TGP2) and the total general labor hours payable on the third shift (TGP3).

8A GSLP1.K=GSLHA.K-TGP2.K-TGP3.K (B153)

Equation B154 defines the general and service overtime required on the second shift (GSOR2) to be equal to the difference between the general and service labor hours required (GSLHR) and the general and service labor effective hours (GSLEH).

7A GSOR2.K=GSLHR.K-GSLEH.K (B154)

Equation B155 defines the general and service overtime payable on the second shift (GSOP2) to be equal to the general and service overtime required on the second shift (GSOR2) if the general and service overtime required on the second shift is equal to or greater than zero; otherwise, it is defined as equal to zero.

51A GSOP2.K=CLIP(GSOR2.K,0,GSOR2.K,0) (B155)

Equation B156 defines the general and service labor cost on the first shift (GSLC1) to be equal to the product of the general and service labor hours payable on the first shift (GSLP1) and the general and service hourly labor rate (GSHLR) plus the product of excess labor (EL) and the general and service labor monthly rate (GSLMR).

15A GSLC1.K=(GSLP1.K)(GSHLR.K)+(EL.K)(GSLMR.K) (B156)

Equation B157 defines the excess labor (EL) to be a table function of time (TIME) starting with 44 and ending with 60 in increments of one week. Equation B158 assigns table values to excess labor (EL) corresponding to the above incremental values of time (TIME).

58A EL.K=TABHL(TEL,TIME.K,44,60,1) (B157)

C TEL*=0/2/2/6/6/6/7/7/8/8/8/9/9/9/9/9/9 (B158)

The need for including the variable "excess labor" is explained in

Chapter V of this study, which is concerned with simulation results. Briefly stated, a lack of correspondence between model-generated labor quantity and actual labor quantity, in the last half of the fifth year of simulation, resulted in non-comparability of other variables. In order to provide reasonably close correspondence of labor quantity in the last year of simulation, an excess labor quantity was added. Some possible explanations for this lack of correspondence are discussed in Chapter V of this study.

Equation B159 defines the general and service regular labor cost on the second shift (GSC2R) to be equal to the product of the total general labor hours payable on the second shift (TGP2), the shift differential for the second shift (SD2A), and the general and service hourly labor rate (GSHLR). The second-shift pay differential at the ABC Company during the simulation period was five per cent.

13A GSC2R.K=(TGP2.K)(SD2A)(GSHLR.K) (B159)

Equation B161 defines the general and service hourly labor rate (GSHLR) to be equal to the general and service labor monthly rate (GSLMR) divided by the labor hours per month (LHPM).

20A GSHLR.K=GSLMR.K/LHPM (B161)

Equation B163 defines the general and service labor monthly rate (GSLMR) to be a table function of time (TIME) starting with one and ending with 58 in increments of three months. Equation B164 assigns table values to the general and service labor monthly rate (GSLMR) corresponding to the above incremental values of time (TIME).

```
58A     GSLMR.K=TABHL(TGSMR,TIME.K,1,58,3)                      (B163)
C       TGSMR*=221/252/255/244/264/286/282/285/303/302/302/
            306/300/317/303/295/293/289/275/298                 (B164)
```

The values assigned to the general and service labor monthly rate were determined by averaging the pay of factory employees of the ABC Company. Payroll data for the ABC Company are contained in Appendix E of this report.

Equation B165 defines general and service labor cost for second-shift overtime (GSC2O) to be equal to the product of the general and service labor overtime hours payable for the second shift (GSOP2), 1.5, and the general and service hourly labor rate (GSHLR).

```
13A     GSC2O.K=(GSOP2.K)(1.5)(GSHLR.K)                         (B165)
```

Equation B166 defines the general and service labor cost for the second shift (GSLC2) to be equal to the sum of the general and service regular labor cost for the second shift (GSC2R) and the general and service overtime labor cost for the second shift (GSC2O).

```
7A      GSLC2.K=GSC2R.K+GSC2O.K                                 (B166)
```

Equation B167 defines the general and service labor cost for the third shift (GSLC3) to be equal to the product of the total general labor hours payable on the third shift (TGP3), the shift differential for the third shift (SD3A), and the general and service hourly labor rate (GSHLR). The ABC Company third-shift pay differential during the simulation period was seven per cent.

13A GSLC3.K=(TGP3.K)(SD3A)(GSHLR.K) (B167)

Equation B169 defines the process labor hours available (PLHA) to be equal to the product of the process labor effective hours available (PLEHA) and the process labor quantity (PLQ).

12A PLHA.K=(PLEHA)(PLQ.K) (B169)

Equation B170 defines the process labor effective hours (PLEH) to be equal to the product of the process labor effective hours available (PLEHA) and the effective process labor (EPL). The shop foreman estimated the process labor effective hours available (PLEHA) to be equal to 160.

12A PLEH.K=(PLEHA)(EPL.K) (B170)

Equation B172 defines the process labor hours payable on the first shift (PLP1) to be equal to the process labor hours available (PLHA) less the process hours payable on the second and third shifts (PHP2, PHP3).

8A PLP1.K=PLHA.K-PHP2.K-PHP3.K (B172)

Equation B173 defines the process labor overtime hours required for the second shift (POR2) to be equal to the process labor hours required in total (PLHRT) less the process labor effective hours (PLEH).

7A POR2.K=PLHRT.K-PLEH.K (B173)

Equation B174 defines the process labor overtime payable on the second shift (PLOP2) to be equal to the process labor overtime hours required (POR2), if the process labor overtime hours required (POR2) are equal to or greater than zero; otherwise, it is defined as equal to zero.

51A PLOP2.K=CLIP(POR2.K,0,POR2.K,0) (B174)

Equation B175 defines the process labor cost for the first shift (PLC1) to be equal to the product of the process labor hours payable for the first shift (PLP1) and the process hourly labor rate (PHLR).

12A PLC1.K=(PLP1.K)(PHLR.K) (B175)

Equation B176 defines the process regular labor cost (PLC2R) to be equal to the product of the process hours payable on the second shift (PHP2), the shift differential for the second shift (SD2A), and the process hourly labor rate (PHLR).

13A PLC2R.K=(PHP2.K)(SD2A)(PHLR.K) (B176)

Equation B177 defines the process hourly labor rate (PHLR) to be equal to the process labor monthly rate (PLMR) divided by the labor hours per month (LHPM).

20A PHLR.K=PLMR.K/LHPM (B177)

Equations B178 and B179 are a formulation for process labor comparable to equations B163 and B164 for general and service labor.

Equation B180 defines the process labor overtime cost for the second shift (PLC2O) to be equal to the product of the process overtime labor payable on the second shift (PLOP2), 1.5, and the process hourly labor rate (PHLR).

13A PLC2O.K=(PLOP2.K)(1.5)(PHLR.K) (B180)

Equation B181 defines the process labor cost for the second shift (PLC2) to be equal to the sum of the process regular labor cost for the second shift (PLC2R) and the process overtime labor cost for the second shift (PLC2O).

7A PLC.2K=PLC2R.K+PLC2O.K (B181)

Equation B182 defines the process labor cost for the third shift (PLC3) to be equal to the product of the process hours payable on the third shift (PHP3), the shift differential for the third shift (SD3A), and the process hourly labor rate (PHLR).

13A PLC3.K=(PHP3.K)(SD3A)(PHLR.K) (B182)

Cost of Goods Manufactured Sector

The cost of goods manufactured sector is a formulation, based on regression of the 60 months of actual data, for estimating the direct manufacturing cost of products sold during each month, mainly as a function of the volume of sales of each product group. The main material employed in the process, coded as P, is a major component of the direct manufacturing cost, as is factory labor. Some direct manufacturing costs, however, were formulated as functions of such variables as machinery and equipment depreciated value, factory labor base pay, and total factory labor cost. Figure 18 is a flow diagram of the cost of goods manufactured sector of Model B.

Equation B183 defines the total cost of manufactured goods (TCMG) to be equal to the sum of the total material cost (TMCMG), the factory wage cost (FWCMG), and the total expense cost of manufactured goods (TECMG).

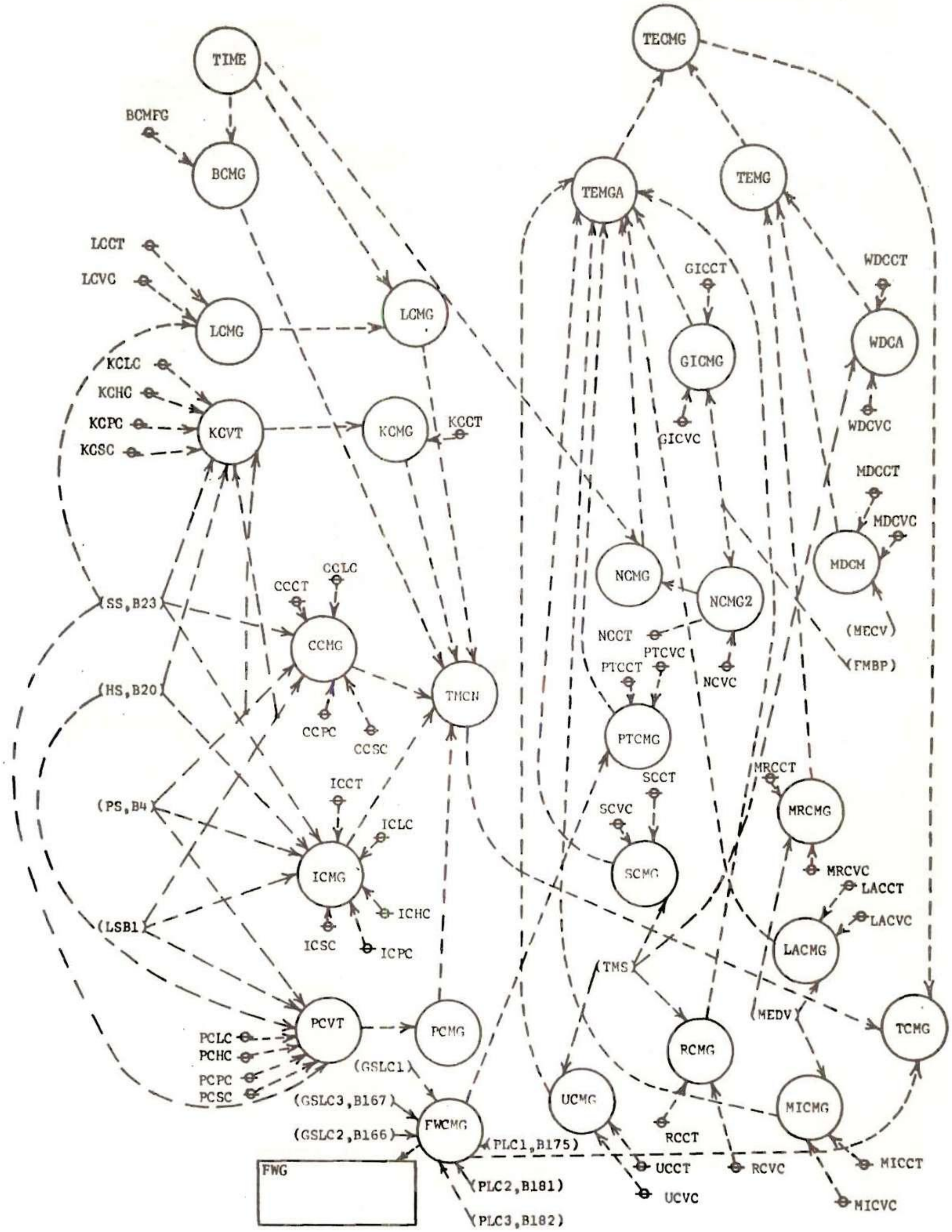


Figure 18. A Flow Diagram of the Cost of Goods

Manufactured Sector of Model B

8A TCMG.K=TMCMG.K+FWCMG.K+TECMG.K (B183)

Equation B184 defines the total material cost of manufactured goods (TMCMG) to be equal to the sum of the material P cost (PCMG), material I cost (ICMG), material C cost (CCMG), material K cost (KCMG), material B cost (BCMG), and material L cost (LCMG).

10A TMCMG.K=PCMG.K+ICMG.K+CCMG.K+KCMG.K+BCMG.K+LCMG.K (B184)

Equation B185 defines the factory wage cost (FWCMG) to be equal to the product of the vacation pay factor (VACPF) and the factory wage cost less vacation pay (FWCLV). The vacation pay factor value was determined by comparing the actual regular and vacation pay for the five-year period of interest for the ABC Company.

12A FWCMG.K=(VACPF)(FWCLV.K) (B185)

Equation B186 defines the factory wage cost less vacation pay (FWCLV) to be equal to the sum of the general and service labor cost for shifts one, two and three (GSLC1, GSLC2, GSLC3) and the process labor cost for shifts one, two and three (PLC1, PLC2, PLC3).

10A FWCLV.K=GSLC1.K+GSLC2.K+GSLC3.K+PLC1.K+PLC2.K+PLC3.K (B186)

Equation B188 defines the material P cost (PCMG) to be equal to the sum of the material P constant term (PCCT) and the material P variable term (PCVT).

7A PCMG.K=PCCT+PCVT.K (B188)

Equation B190 defines the material P variable term (PCVT) to be equal to the sum of products of the material P product L coefficient (PCLC) and the product L sales (LS), the material P product H coefficient (PCHC) and the product H sales (HS), the material P product P coefficient (PCPC) and the product P sales (PS), and the material P product S coefficient (PCSC) and the product S sales (SS).

16A PCVT.K=(PCLC)(LS.K)+(PCHC)(HS.K)+(PCPC)(PS.K)+PCSC)(SS.K) (B190)

Equations B188 and B190 are a multiple linear regression estimate of material P cost, based on regression analysis of the five years of ABC Company information. Regression analysis was made by utilizing the Burroughs B5500 computer at the Georgia Institute of Technology. The multiple linear regression program employed was developed by Mr. Charles L. Clark (2) of the Burroughs Corporation.

The remainder of the cost of goods manufactured sector contains regression relationships similar to that above for material P and, therefore, will not be described in detail in this description.

Operating Costs Sector

This sector contains the formulation for all items included in the profit and loss statement of the ABC Company. As in the case of direct manufacturing costs, operating costs are estimated as regression functions of variables such as product sales, factory labor wages, professional labor wages, and equipment depreciated value. Figure 19 is a flow diagram of the operating costs sector of Model B.

Equation B255 defines the gross profit (GP) to be equal to the total sales (TS) less the inventory adjustment (IA), the total cost of manufactured goods (TCMG), and the freight costs (FC).

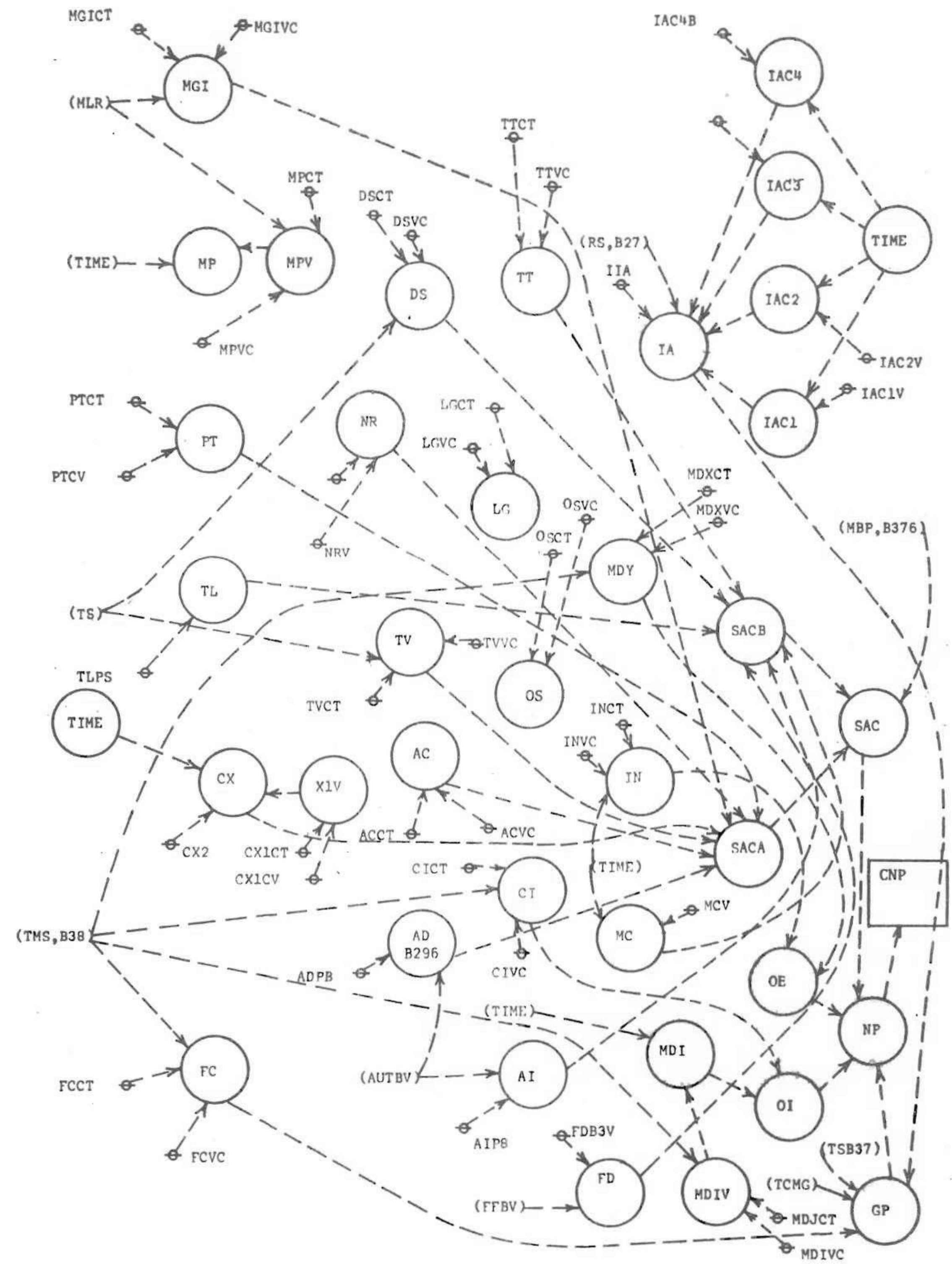


Figure 19. A Flow Diagram of the Operating Costs Sector of Model B

9A GP.K=TS.K-IA.K-TCMG.K-FC.K (B255)

Equation B256 defines the inventory adjustment (IA) to be equal to the purchased product sales (RS) less the initial inventory adjustment (IIA), inventory adjustment change one (IAC1), inventory adjustment change two (IAC2), inventory adjustment change three (IAC3), and inventory adjustment change four (IAC4).

10A IA.K=RS.K-IIA-IAC1.K-IAC2.K-IAC3.K-IAC4.K (B256)

Equations B257 to B265 provide step changes in inventory to allow the inventory adjustment (IA) to correspond to actual inventory adjustments in the ABC Company. Inventory adjustment changes were based on yearly averages for the five-year period under consideration.

Equation B266 defines the freight cost (FC) to be equal to the sum of the freight cost constant term (FCCT) and the product of the freight cost variable coefficient (FCVC) and the total manufactured sales (TMS).

14A FC.K=FCCT+(FCVC)(TMS.K) (B266)

The freight cost estimating equation (B266) is based on a linear regression of past information for the ABC Company. The remainder of the operating costs sector contains regression-derived equations for estimating individual operating costs. Since they are formulated in a similar manner to the equation for freight cost (FC), a detailed description of each operating cost will not be developed.

Equipment Status Sector

The equipment status sector contains formulations for equipment acquisition and retirement. The existing policy for equipment acquisition involved comparing required and available hours for each type of equipment. Existing policy was such that some equipment, because of its high initial cost, was allowed to run on almost a three-shift loading before additional equipment was acquired, whereas other equipment was purchased as soon as a two-shift loading was reached. Figure 20 is a flow diagram of the equipment status sector of Model B.

Equation B333 defines the machine C acquisition rate (CAR) to be equal to one if the machine C acquisition ratio (CMAR) is equal to or greater than the machine C acquisition ratio policy (CMARP); otherwise, it is defined as equal to zero.

51R CAR.KL=CLIP(1,0,CMAR.K,CMARP) (B333)

Equation B334 defines the machine C acquisition ratio (CMAR) to be equal to the machine C hours required (CMHR) divided by the machine C hours available (CMHA).

20A CMAR.K=CMHR.K/CMHA.K (B334)

Equation B335 assigns the value of 1.8 to the machine C acquisition ratio policy (CMARP) variable.

C CMARP=1.8 (B335)

Acquisition ratio policy values were determined by asking the shop foreman of the ABC Company to indicate at what point in the loading of each machine type an additional equipment unit would be purchased.

Equation B336 defines the machine C quantity (CQ) at time K to be equal to the machine C quantity at time J plus the difference between the

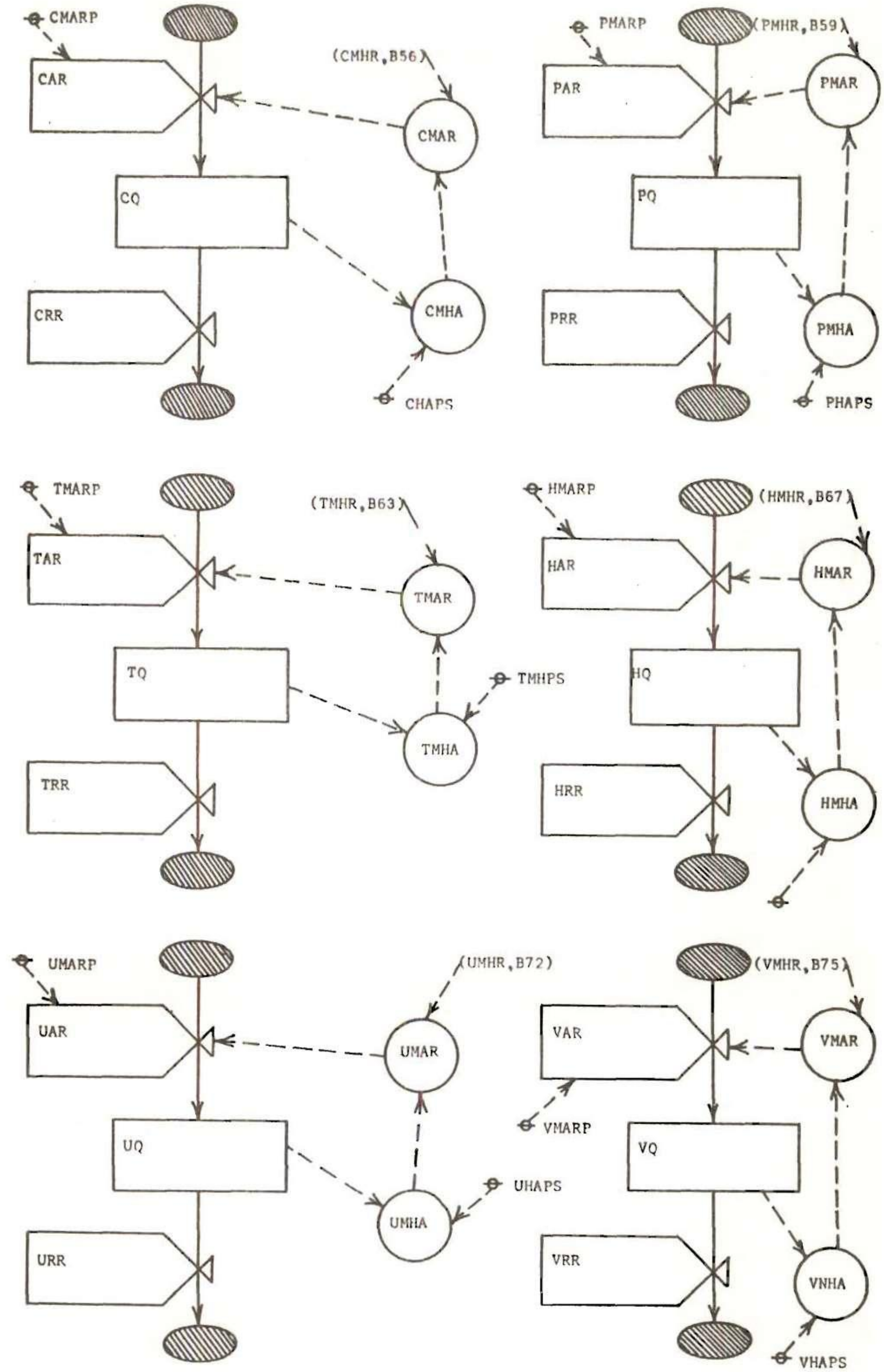


Figure 20. A Flow Diagram of the Equipment Status Sector of Model B

machine C acquisition rate (CAR) and the machine C retirement rate (CRR) during the interval JK.

1L CQ.K=CA.J+(DT)(CAR.JK-CRR.JK) (B336)

Equation B337 defines the machine C retirement rate (CRR) to be equal to zero.

6R CRR.KL=0 (B337)

Since the equipment employed in the ABC Company was fairly new, of standard design, and unlikely to be obsolete or replaced for any other reason in the near future, the most appropriate retirement policy for the simulation period of interest was assumed to be no retirement.

Equations B338 to B362 are formulations similar to the above for machine types H, U, T, P and V.

Labor Status Sector

The labor status sector is a formulation for factory labor acquisition, training, transfer and attrition. It also includes formulations for specifying the desired ratio of service and professional labor as a function of direct factory labor. Direct factory labor is subdivided into two labor groups: specifically, general factory labor and process labor. This division of labor was formulated to more accurately determine labor costs since the processing labor average wage was considerably in excess of the general labor average wage. Service labor wages were averaged with general factory labor wages since their average wages were similar. Figure 21 is a flow diagram of the labor status sector of Model B.

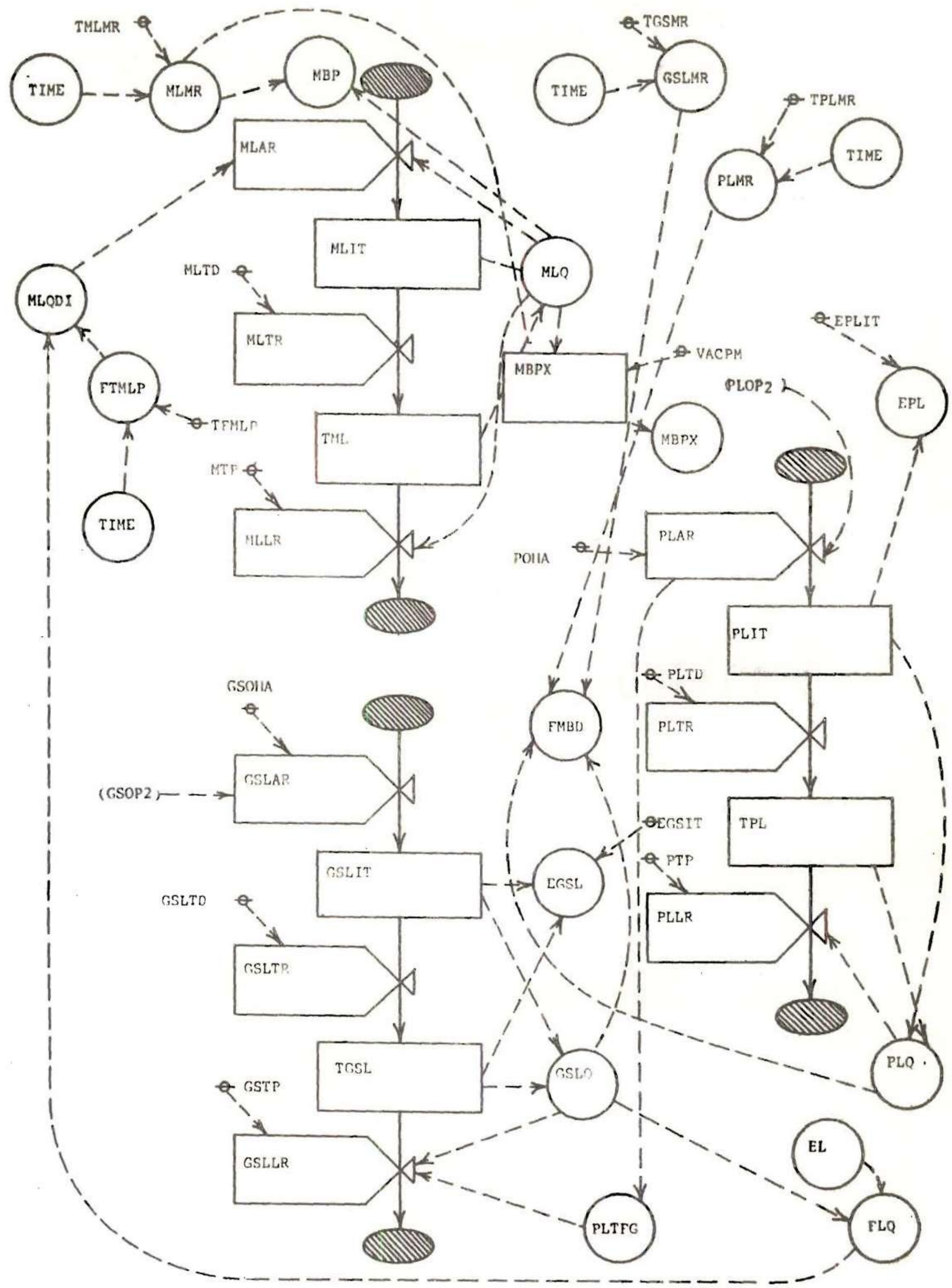


Figure 21. A Flow Diagram of the Labor Status Sector of Model B

The labor status formulation, although set equal to actual values initially, is self-generating and therefore serves as a means for comparing industrial dynamics-generated level values with actual level values. Problems encountered in the fifth year of the five-year simulation period are discussed in Chapter V of this report.

Equation B363 defines the management labor in training (MLIT) at time K to be equal to the management labor in training at time J plus the difference between the management labor acquisition rate (MLAR) and the management labor training rate (MLTR) during the interval JK.

1L MLIT.K=MLIT.J+(DT)(MLAR.JK-MLTR.JK) (B363)

Equation B364 defines the management labor acquisition rate (MLAR) to be equal to one if the managment labor quantity desired indicator (MLQDI) is equal to or greater than the management labor quantity (MLQ); otherwise, it is defined as equal to zero.

51R MLAR.KL=CLIP(1,0,MLQDI.K,MLQ.K) (B364)

Equation B365 defines the management labor quantity (MLQ) to be equal to the sum of the management labor in training (MLIT) and the trained management labor (TML).

7A MLQ.K=MLIT.K+TML.K (B365)

Equation B366 defines the management labor quantity desired indicator (MLQDI) to be equal to one-half plus the product of the factory labor quantity (FLQ) and the factory to management labor percentage (FTMLP).

14A MLQDI.K=0.50+(FLQ.K)(FTMLP.K) (B366)

The above formulation assumes that additional employee demand of less than one-half of a man should not require hiring another management employee.

Equation B367 defines the factory to management labor percentage (FTMLP) to be a table function of time (TIME), starting with 6 and ending with 54 in increments of 12 months. Equation B368 assigns table values of the factory to management labor percentage (FTMLP) corresponding to the above incremental values of time (TIME). The values assigned were developed from ABC Company information for the five-year simulation period.

58A FTMLP.K=TABHL(TFMLP,TIME.K,6,54,12) (B367)

C TFMLP*=0.446/0.507/0.482/0.429/0.387 (B368)

Equation B369 defines the management labor monthly rate (MLMR) to be a table function time (TIME), starting at one and ending at 58 in increments of three months. Equation B370 assigns table values to the management labor monthly rate (MLMR) corresponding to the above incremental values of time (TIME). The values assigned were taken from payroll information for ABC Company for the five-year simulation period.

58A MLMR.K=TABHL(TMLMR,TIME.K,1,58,3) (B369)

C TMLMR*=582/591/501/545/500/535/512/547/660/660/
670/758/743/772/773/700/655/630/640/629 (B370)

Equation B371 defines the trained management labor (TML) at time K to be equal to the trained management labor at time J plus the difference between the management labor training rate (MLTR) and the management labor leaving rate (MLLR) for the interval JK.

1L TML.K=TML.J+(DT)(MLTR.JK-MLLR.JK) (B371)

Equation B372 defines the managment labor training rate (MLTR) to be equal to the management labor in training (MLIT) divided by the management labor training delay (MLTD). The plant superintendent of the ABC Company estimated 12 months as an appropriate management labor training delay (MLTD).

20R MTR.KL=MLIT.K/MLTD (B372)

Equation B374 defines the management labor leaving rate (MLLR) to be equal to the product of the management turnover percentage (MTP) and the management labor quantity (MLQ). The management turnover percentage was determined from payroll information of the ABC Company.

12R MLLR.KL=(MTP)(MLQ.K) (B374)

Equation B376 defines the management base pay (MBP) to be equal to the product of the management labor quantity (MLQ), the management labor monthly rate (MLMR), and the vacation percentage for management (VACPM). The vacation percentage factor for management was estimated, on the basis of a two-week vacation policy, to be approximately four per cent.

13A MBP.K=(MLQ.K)(MLMR.K)(VACPM) (B376)

Equation B378 defines the general and service labor in training (GSLIT) at time K to be equal to the general and service labor in training at time J plus the difference between the general and service labor acquisition rate (GSLAR) and the general and service labor training rate (GSLTR) during interval JK.

1L GSLIT.K=GSLIT.J+(DT)(GSLAR.JK-GSLTR.JK) (B378)

Equations B490 and B491 are defined in the policy variables and constants sector.

Equation B379 assigns a value of 352 to the general and service overtime hours allowed (GSOHA). The shop foreman of the ABC Company indicated that four men working four hours of overtime was considered as enough overtime to require hiring an additional employee. For a normal month of 22 working days, the overtime hours per month would be 351.

C GSOHA=352 (B379)

Equation B380 defines the general and service labor training rate (GSLTR) to be equal to the general and service labor in training (GSLIT) divided by the general and service labor training delay (GSLTD). The training delay was estimated by the shop foreman of ABC Company to be five months.

20R GSLTR.KL=GSLIT.K/GSLTD (B380)

Equation B382 defines the trained general and service labor (TGSL) at time K to be equal to the trained general and service labor at time J plus the difference between the general and service labor training rate (GSLTR) and the general and service labor leaving rate (GSLLR) during interval JK.

1L TGSL.K=TGSL.J+(DT)(GSLTR.JK-GSLLR.JK) (B382)

Equation B383 defines the general and service labor leaving rate (GSLLR) to be equal to the product of the general and service turnover percentage (GSTP) and the general and service labor quantity (GSLQ) plus the process labor transferred from general (PLTFG).

15R GSLLR.KL=(GSTP)(GSLQ.K)+(GLTFG.K)(1) (B383)

Equation B384 defines the process labor transferred from general (PLTFG) to be equal to one if the process labor acquisition rate (PLAR) is equal to or greater than one; otherwise, it is defined as equal to zero. This formulation was developed because process labor additions in the ABC Company were made from the general labor pool.

51A PLTFG.K=CLIP(1,0,PLAR.JK,1) (B384)

Equation B385 defines the general and service labor quantity (GSLQ) to be equal to the sum of the general and service labor in training (GSLIT) and the trained general and service labor (TGSL).

7A GSLQ.K=GSLIT.K+TGSL.K (B385)

Equation B387 defines the effective general and service labor (EGSL) to be equal to the sum of the trained general and service labor (TGSL) and the product of the effectiveness of general and service labor in training (EGSIT) and the general and service labor in training (GSLIT). The shop foreman of the ABC Company estimated the effectiveness of general and service employees in training to be 50 per cent.

14A EGSL.K=TGSL.K+(EGSIT)(GSLIT.K) (B387)

Equation B389 defines the process labor in training (PLIT) at time K to be equal to the process labor in training at time J plus the difference between the process labor acquisition rate (PLAR) and the process labor training rate (PLTR) during interval JK.

1L PLIT.K=PLIT.J+(DT)(PLAR.JK-PLTR.JK) (B389)

Equation B390 assigns a value of 264 to the process overtime hours allowed (POHA). The estimated limit for overtime was expressed as two process men working six hours of overtime per day. A normal month of 22 working days would, therefore, allow 264 overtime hours.

C POHA=264 (B390)

Equation B391 defines the process labor training rate (PLTR) to be equal to the process labor in training (PLIT) divided by the process labor training delay (PLTD). The process labor training delay was estimated by the shop foreman of the ABC Company to be 12 months.

20R PLTR.KL=PLIT.K/PLTD (B391)

Equation B393 defines the trained process labor (TPL) at time K to be equal to the trained process labor at time J plus the difference between the process labor training rate (PLTR) and the process labor leaving rate (PLLR) during interval JK.

1L TPL.K=TPL.J+(DT)(PLTR.JK--PLLR.JK) (B393)

Equation B394 defines the process labor leaving rate (PLLR) to be equal to the product of the process turnover percentage (PTP) and the process labor quantity (PLQ). The process turnover percentage for the ABC Company was zero for the five-year period of interest.

12R PLLR.KL=(PTP)(PLQ.K) (B394)

Equation B396 defines the effective process labor (EPL) to be equal to the trained process labor plus the product of the effectiveness of process labor in training (EPLIT) and the process labor in training (PLIT). The shop foreman of the ABC Company estimated that process labor in training was eighty per cent effective.

14A EPL.K=TPL.K+(EPLIT)(PLIT.K) (B396)

Equation B398 defines the process labor quantity (PLQ) to be equal to the sum of the process labor in training (PLIT) and the trained process labor (TPL).

7A PLQ.K=PLIT.K+TPL.K (B398)

Equation B399 defines the factory monthly base pay (FMBP) to be equal to the sum of the product of the general and service labor quantity (GSLQ) and the general and service labor monthly rate (GSLMR) and the product of the process labor quantity (PLQ) and the process labor monthly rate (PLMR).

15A FMBP.K=(GSLQ.K)(GSLMR.K)+(PLQ.K)(PLMR.K) (B399)

Equation B400 defines the factory labor quantity (FLQ) to be equal the sum of the general and service labor quantity (GSLQ), the process labor quantity (PLQ), and the excess labor (EL).

8A FLQ.K=GSLQ.K+PLQ.K+EL.K (B400)

Fixed Assets Sector

The fixed assets sector of the model is a formulation to allow specification of the fixed asset levels of the ABC Company. Since overall fixed asset policies, excluding those related to processing equipment, were difficult to formulate in terms of self-generated levels because of lack of definition of factors causing fixed asset acquisition, fixed asset variables were formulated as step functions in line with actual increases in fixed asset value during the 60-month period. Equipment acquisition, however, was developed as a self-generating formulation; it is a function of sales demand and equipment acquisition policy. Figure 22 is a flow diagram of the fixed assets sector of Model B indicating interconnection between variables.

The ABC Company model was developed to compare the profit rather than the net worth correspondence of the simulation model with actual past data. Although fixed asset levels are not required relative to a net worth calculation, some operating expenses, such as machinery and equipment depreciation expense, were developed as functions of fixed assets levels. Fixed asset levels, therefore, are developed in the fixed assets sector to serve as a basis for estimating related operating expenses.

Equation B401 defines the machinery and equipment cost value (MEDV) at time K to be equal to the machinery and equipment cost value at

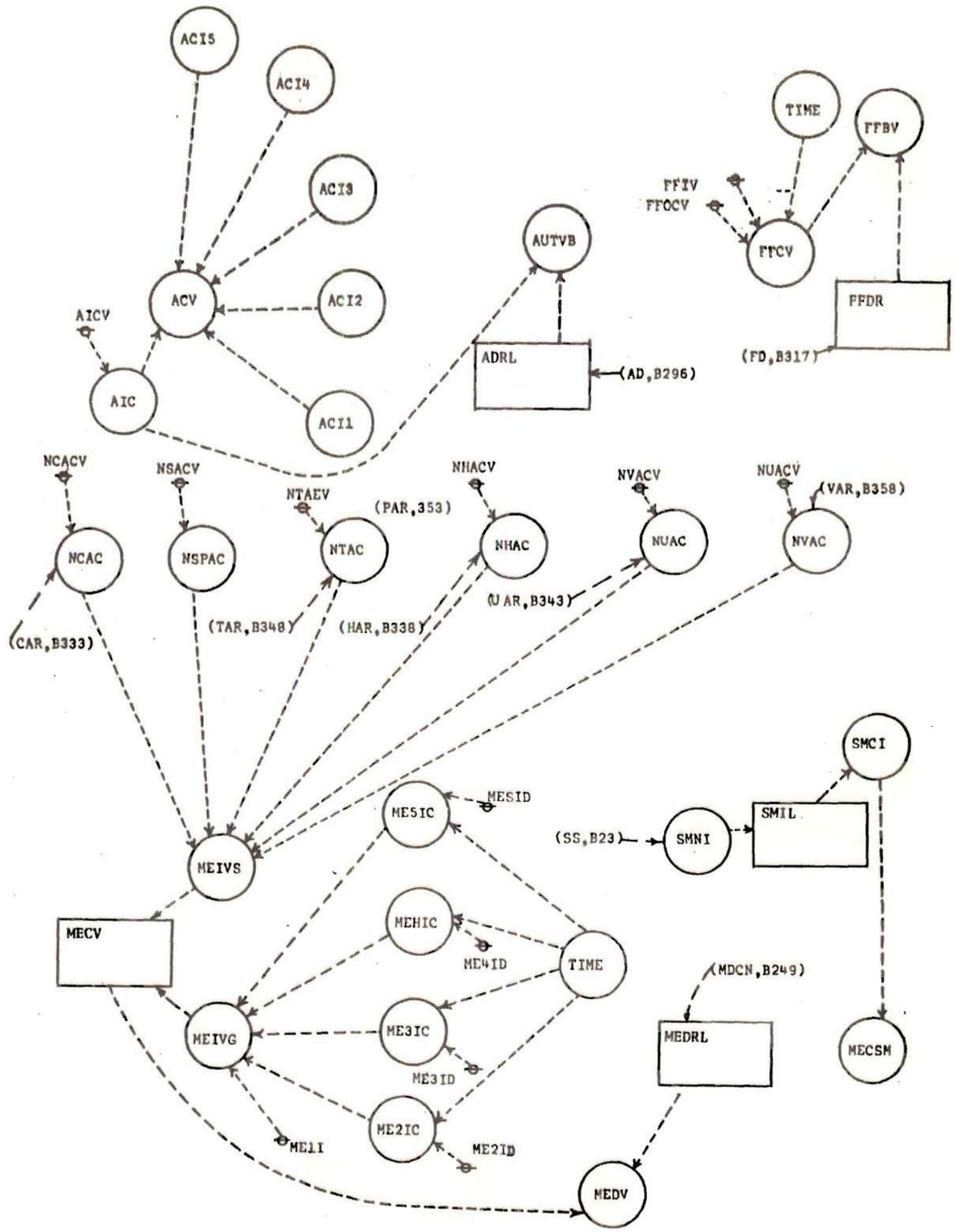


Figure 22. . A Flow Diagram of the Fixed Assets Sector of Model B

time J plus the sum of the general machinery and equipment initial value (MEIVG) and the special machinery and equipment initial value (MEIVS).

1L MECV.K=MECV.J+(DT)(MEIVG.J+MEIVS.J) (B401)

Equations B403 to B415 inclusive provide a formulation which allows the general equipment cost level to match that of the ABC Company during the five-year period of interest. Equations B416 to B428 inclusive allow adjustment of the machinery and equipment cost level to reflect acquisition of additional processing equipment.

Equation B429 defines the machinery and equipment depreciated value (MEDV) to be equal to the machinery and equipment cost value (MECV) less the machinery and equipment depreciation level (MEDRL).

7A MEDV.K=MECV.K-MEDRL.K (B429)

Equation B431 defines the automobile book value (AUTBV) to be equal to the difference between the automobile cost value (ACV) and the automobile depreciation level (ADRL).

7A AUTBV.K=ACV.K-ADRL.K (B431)

Equations B432 to B444 inclusive are a formulation for automobile book value corresponding to that for the ABC Company to serve as a basis for some operating expenses which are estimated as a function of the automobile cost value.

Equation B445 defines the automobile depreciation level (ADRL) at time K to be equal to the automobile depreciation level at time J plus the automobile depreciation (AD) during the interval JK.

1L ADR.K=ADRL.J+(DT)(AD.J+0) (B445)

Equations B446 to B450 inclusive are a formulation to represent the level of furniture and fixtures used by the ABC Company during the five-year period of interest.

Equation B451 defines the cumulative net profit (CNP) at time K to be equal to the cumulative net profit at time J plus the net profit (NP) during interval JK. This variable is shown in Figure 19.

1L CNP.K=CNP.J+(DT)(NP.J+0) (B451)

Equation B452 defines the cumulative factory wage (FWG) at time K to be equal to the cumulative factory wage at time J plus the factory wage cost (FWCMG) during interval JK. This variable is shown in Figure 18.

1L MBPX.K=MBPX.J+(DT)(MBP.J+0) (B454)

Equations B456 to B489 inclusive are initial condition equations. These equations were assigned values corresponding to the ABC Company information at the beginning of the five-year period of interest.

Policy Variables and Constants Sector

The following formulations represent actual policies employed by the ABC Company during the five-year period of interest.

Equation B490 defines the general and service labor acquisition rate (GSLAR) to be equal to one if the general and service overtime payable on the second shift (GSOP2) is equal to or greater than the general and service overtime hours available (GSOHA); otherwise, it is defined as equal to zero.

51R GSLAR.KL=CLIP(1,0,GSOP2.K,GSOHA) (B490)

Equation B491 defines the process labor acquisition rate (PLAR) to be equal to one if the process labor overtime payable on the second shift (PLOP2) is equal to or greater than the process overtime hours available (POHA); otherwise, it is defined as equal to zero.

51R PLAR.KL=CLIP(1,0,PLOP2.K,POHA) (B491)

Equation B492, which requires seven data cards, specifies the variables to be printed in tabular form as output.

Equation B493 specifies the variables to be plotted.

Equation B494 specifies the length of the simulation interval, the length of the simulation in intervals, the frequency of printed output in increments of DT intervals, and the frequency of plotting in increments of DT intervals.

CHAPTER IV

REVISED POLICIES

General Description

Both models A and B, described in the previous chapters, incorporate assumed existing policy alternatives. In the case of Model A, certain policies are assumed to be in existence in the hypothetical company, whereas, in Model B, the existing set of policy alternatives describes the policies employed in the ABC Company during the period of interest.

Six revised policies were considered, developed and employed; four were employed with Model A and two with Model B. The six revised policies are as follows:

1. Accelerated Depreciation
2. Internally Generated Growth
3. Minimum Next-Period Cost Replacement Policy
4. A Labor to Equipment Factor Change
5. A Hiring Policy Reformulation
6. An Equipment Purchase Deferral

Computer runs employing the revised policies were made for models A and B, and results relative to company growth were obtained and compared. A detailed description of each of the six revised policy formulations follows.

Policy 1: Accelerated Depreciation

Existing policy for Model A assumes that the straight-line depreciation method is to be employed. Policy 1, as an alternative, represents a formulation for the double-declining balance method of depreciation. Policy 1 was compared with existing policy in an effort to determine the relative effect on company growth of employing these two different depreciation methods for the model developed.

Equation A1088, A1089 and A1090 define depreciation expense for processes one, two and three, respectively, under existing policy. By successively considering equations A711, A623 and A620, it is apparent that the table values assigned to equation A206 determine the depreciation schedule employed over time for process one equipment.

The following is a listing of the Policy 1 set of equations which were substituted for equations A1088, A1089 and A1090 in order to consider the effect of employing accelerated depreciation:

12A	P1ED.K=(DDPP1)(P1EBV.K)	(A1121)
C	DDPP1=0.00965	(A1122)
12A	P2ED.K=(DDPP2)(P2EBV.K)	(A1123)
C	DDPP2=0.00965	(A1124)
12A	P3ED.K=(DDPP3)(P3EBV.K)	(A1125)
C	DDPP3=0.00965	(A1126)

The rate of depreciation under the double-declining balance method is obtained by taking twice the reciprocal of the number of depreciation expense periods to be applied in the equipment depreciation calculation. In Model A, all units of equipment under the existing policy formulation were assumed to have useful lives of four years, and since depreciation expense was computed on a weekly basis, there were 208 depreciation expense periods. Therefore, the double-declining percentage for process one (DDPP1) was calculated as follows:

$$\text{DDPP1} = \frac{2}{208} = 0.00965 \quad \text{or} \quad 0.965\%$$

Since units of process equipment in process two and three also were assumed to have four-year lives for depreciation purposes, the double-declining percentage for those processes is equal to the process one percentage value.

Under the double-declining balance method, the double-declining percentage is applied initially to the first cost value of the equipment item in question, ignoring salvage value, and is then successively applied to the book value net of depreciation applied to the unit, for all remaining periods. Therefore, process one equipment depreciation (P1ED) is defined in equation A1121 as the product of the double-declining percentage for process one (DDPP1) and the process one equipment book value (P1EBV). Similar formulations follow equation A1121 for processes two and three.

Policy 2: Internally Generated Growth

Policy 2 is a formulation for an alternative basic financial policy. The existing policy formulation assumes that if additional funds are needed relative to demand and unavailable from cash, and the interest rate on borrowed funds is below a defined maximum, an increment of debt funds will be acquired. Therefore, under defined restrictions, assumed existing policy is not restricted to internally generated growth. As indicated in Appendix A, equation A1091 for existing policy allows the debt capital input rate (DCIR) to be non-zero if specified conditions are met.

Policy 2, however, was formulated to determine the relative effect on company growth of limiting growth fund sources to internally generated funds. Therefore, Policy 2 specifies the debt capital input rate to be equal to zero. Equation A1127, for instrumenting Policy 2, defines the debt capital input rate to be equal to zero.

6A	DCIR.K=0	(A1127)

In employing Policy 2, therefore, equation A1127 is substituted for equation A1091 in Model A.

Policy 3: Minimum Next-Period Cost Replacement Policy

Under assumed existing policy for Model A, replacement of a specific process unit occurs when the reliability of the process unit goes below a defined minimum acceptable reliability level for that process equipment type, if the equipment unit has been in service beyond a minimum time period.

Equation A1092, listed in Appendix A, allows the minimum reliability signal for process one machine one (MR11S) to be equal to zero if the process one machine one reliability (P11R) is less than the acceptable reliability indicator for process one machine one (ARI11).

The following is a listing of the Policy 3 formulation:

15A	YCRV1.K=(M1LS)(CRF5.K)+(SV11)(IR.K)	(A1128)
7A	M1LS.K=P1IEC-SV11	(A1129)
58A	CRF5.K=TABHL(TCRF5,IR.K,0.06,0.15,0.03)	(A1130)
C	TCRF5*=0.2374/0.25713/0.27741/029832	(A1131)

20A	WCRV1.K=YCRV1.K/52	(A1132)
C	IE1=60	(A1133)
7A	CHC1.K=WCRV1.K+IE1	(A1134)
51A	MRS11.K=CLIP(0,1,EP1M1.K,CHC1.K)	(A1135)
51A	MRS12.K=CLIP(0,1,EP1M2.K,CHC1.K)	(A1136)
51A	MRS13.K=CLIP(0,1,EP1M3.K,CHC1.K)	(A1137)
51A	MRS14.K=CLIP(0,1,EP1M4.K,CHC1.K)	(A1138)
51A	MRS15.K=CLIP(0,1,EP1M5.K,CHC1.K)	(A1139)
51A	MR11S.K=CLIP(0,1,E11.K,CHC1.K)	(A1140)
51A	MR12S.K=CLIP(0,1,E12.K,CHC1.K)	(A1141)
51A	MR13S.K=CLIP(0,1,E13.K,CHC1.K)	(A1142)
51A	MR14S.K=CLIP(0,1,E14.K,CHC1.K)	(A1143)
51A	MR15S.K=CLIP(0,1,E15.K,CHC1.K)	(A1144)
15A	YCRV2.K=(M2LS)(CRF5.K)+(SV21)(IR.K)	(A1145)
7A	M2LS.K=P2IEC-SV21	(A1146)
20A	WCRV2.K=YCRV2.K/52	(A1147)
C	IE2=45	(A1148)
7A	CHC2.K=WCRV2.K+IE2	(A1149)
51A	MRS21.K=CLIP(0,1,EP2M1.K,CHC2.K)	(A1150)
51A	MRS22.K=CLIP(0,1,EP2M2.K,CHC2.K)	(A1151)
51A	MRS23.K=CLIP(0,1,EP2M3.K,CHC2.K)	(A1152)
51A	MRS24.K=CLIP(0,1,EP2M4.K,CHC2.K)	(A1153)
51A	MRS25.K=CLIP(0,1,EP2M5.K,CHC2.K)	(A1154)
51A	MR21S.K=CLIP(0,1 E21.K,CHC2.K)	(A1155)
51A	MR22S.K=CLIP(0,1,E22.K,CHC2.K)	(A1156)
51A	MR23S.K=CLIP(0,1,E23.K,CHC2.K)	(A1157)

15A YCRV3.K=(M3LS)(CRF5.K)+(SV31)(IR.K) (A1158)

7A M3LS.K=P3IEC-SV31 (A1159)

20A WCRV3.K=YCRV3.K/52 (A1160)

C IE3=38 (A1161)

7A CHC3.K=WCRV3.K+IE3 (A1162)

51A MRS31.K=CLIP(0,1,EP3M1.K,CHC3.K) (A1163)

51A MRS32.K=CLIP(0,1,EP3M2.K,CHC3.K) (A1164)

51A MRS33.K=CLIP(0,1,EP3M3.K,CHC3.K) (A1165)

51A MRS34.K=CLIP(0,1,EP3M4.K,CHC3.K) (A1166)

51A MRS35.K=CLIP(0,1,EP3M5.K,CHC3.K) (A1167)

51A MR31S.K=CLIP(0,1,E31.K,CHC3.K) (A1168)

51A MR32S.K=CLIP(0,1,E32.K,CHC3.K) (A1169)

The Policy 3 formulation was an attempt to base the unit replacement decision upon a comparison of the next period cost of operation of a present unit of equipment and its replacement. The Policy 3 formulation affects replacement of an existing unit of equipment when the next period equipment expense for that unit of equipment exceeds the capitalized period cost of replacement with a new equipment unit plus its time dependent operation expense.

Equation A1128 defines the yearly capital recovery value for process one (YCRV1) to be equal to the product of the machine cost for process one less salvage (M1LS) and the capital recovery factor for a five-year interest period (CRF5), plus the product of the salvage value of process one machine one (SV11) and the interest rate (IR).

15A YCRV1.K=(M1LS)(CRF5)+(SV11)(IR.K) (A1128)

Equation A1129 defines the machine cost for process one less salvage (M1LS) to be equal to the difference between the process one initial equipment cost (P1IEC) and the salvage value of process one machine one (SV11).

7A M1LS.K=P1IEC-SV11 (A1129)

Equation A1130 defines the capital recovery factor for a five-year interest period (CRF5) to be a table function of the interest rate (IR) starting with six per cent and ending with 15 per cent in increments of three per cent. Equation A1131 assigns table values to the capital recovery factor for a five-year interest period (CRF5) corresponding to the above increments of the interest rate (IR).

58A CRF5.K=TABHL(TCRF5,IR.K,0.06,0.15,0.03) (A1130)

C TCRF5*=0.2374/0.25713/0.27741/0.29832 (A1131)

The assigned values were taken from the interest tables which constitute Appendix E in Grant's (10) Principles of Engineering Economy.

Equation A1132 defines the weekly capital recovery value for process one (WCRV1) to be equal to the yearly capital recovery value for process one (YCRV1) divided by 52.

20A WCRV1.K=YCRV1.K/52 (A1132)

Equation A1134 defines the challenger cost for process one (CHC1) to be equal to the sum of the weekly capital recovery value for process one (WCRV1) and the initial equipment expense for process one (IE1). The initial equipment expense for process one (IE1) was assigned a value of

60, which is in agreement with equation A163, which assigns equipment expense values as a function of time for process one equipment.

7A CHC1.K=WCRV1.K+IE1 (A1134)

Equation A1135 defines the minimum reliability signal for process one machine one (MRS11) to be equal to one only if the challenger cost for process one (CHC1) is less than the expense for process one machine one (EP1M1).

51A MRS11.K=CLIP(0,1,EP1M1.K,CHC1.K) (A1135)

The Policy 3 set of equations includes similar formulations for other equipment units in process one, as well as similar formulations for processes two and three.

In employing Policy 3, equations A1128 to A1169 inclusive were substituted in Model A for equations A1092 to A1116 inclusive.

Policy 4: A Labor to Equipment Ratio Change

Under existing policy for Model A, the labor to equipment factor (LTEF) was employed in specifying the factory labor desired (FLD) as a function of the factory labor required for equipment (FLRFE) in equation A859. Under assumed existing policy, the labor to equipment factor was assigned a value of 1.05.

Revised Policies 4A and 4B specify values of 1.00 and 1.10, respectively, for the labor to equipment factor. Policy 4A and 4B formulations were employed by adding the following rerun cards immediately following the entire existing policy simulation program deck:

RUN 2 (A1170)

C LTEF=1.00 (A1171)

RUN 3 (A1172)

C LTEF=1.10 (A1173)

The DYNAMO system formulation was developed to execute reruns employing modified constants by simply following the initial model simulation with the above rerun and changed constant value cards.

Policy 5: A Hiring Policy Reformulation

Under assumed existing policy for Model B, the general and service labor acquisition rate (GSLAR) is dependent on a comparison of actual and allowed overtime hours in equation B490. A similar formulation for process labor also exists. When actual overtime exceeds the allowed overtime hours for a month, an additional employee is hired.

The revised policy was developed on a basis similar to that employed in Model A, and the policies were compared relative to their effect on company growth. The following set of equations constitutes the Policy 5 formulation:

20A	GSHPR.K=GSLHR.K/GSLEH.K	(B495)
51R	GSLAR.KL=CLIP(1,0,GSHPR.K,GSHPV)	(B496)
C	GSHPV=1.10	(B497)
20A	PHPR.K=PLHRT.K/PLEH.K	(B498)
51R	PLAR.KL=CLIP(1,0,PHPR.K,PHPV)	(B499)
C	PHPV=1.10	(B500)

Equation B495 defines the general and service hours policy ratio

(GSHPR) to be equal to the general and service labor hours required (GSLHR) divided by the general and service labor effective hours (GSLEH).

20A GSHPR.K=GSLHR.K/GSLEH.K (B495)

Equation B496 defines the general and service labor acquisition rate (GSLAR) to be equal to one if the general and service hours policy ratio (GSHPR) is equal to or greater than the general and service hours policy value (GSHPV); otherwise, it is defined as equal to zero.

51R GSLAR.KL=CLIP(1,0,GSHPR.K,GSHPV) (B496)

Equation B497 assigns the value of 1.10 to the general and service hours policy value (GSHPV).

C GSHPV=1.10 (B497)

A formulation for professional labor patterned after the above completes the initial Policy 5 equation set.

Since the appropriate maximizing values for GSHPV and PHPV could not be predetermined, alternate constant values of 1.05 and 1.15 were employed in reruns of Policy 5; these will be referred to as Policies 5B and 5C. The employment of the initial value of 1.10 will be referred to as Policy 5A. Additional rerun equations employed, which immediately followed the existing policy formulation, were as follows:

RUN 2 (B501)

C GSHPV=1.05 (B502)

C PHPV=1.05 (B503)

RUN 3 (B504)

C GSHPV=1.15 (B505)

C PHPV=1.15 (B506)

Policy 6: An Equipment Purchase Deferral

Under existing policy of the ABC Company, an additional unit of machine C equipment is purchased when the ratio of machine C hours required (CMHR) to machine C hours available (CMHA) reaches a value of 1.8, as indicated in equations B333 to B335.

The Policy 6 formulation considers the effect on company growth of increasing CMARP to 2.8. This policy assumes that machine C equipment will be loaded to almost three shifts before an additional unit is purchased. Policy 6 was affected by specifying a rerun and changing the constant value as follows:

RUN 2 (B507)

C CMARP=2.8 (B508)

CHAPTER V

SIMULATION RESULTS

General Description

The output of a DYNAMO system simulation can be in the form of a tabulation of scaled values of specified variables, a scaled plot of specified variables, or both. The DYNAMO system possesses sufficient capacity to print 140 variables as frequently as each simulation interval or to plot 10 variables as frequently as each simulation interval.

All output for Model A was in the form of 33 variables printed out on a simulated weekly basis and nine variables plotted on a simulated weekly basis for a total simulation period of 104 weeks. Figure 23 is a reduced-scale illustration of the first eight weeks of printed output for assumed existing policies of Model A, and Figure 24 is a reduced-scale illustration of the plotted output for the total simulation period, as produced by the DYNAMO simulation system.

Output for Model B was in the form of 89 variables printed out on a simulated monthly basis and eight variables plotted on a simulated monthly basis for a total simulation period of 60 months. Figure 25 is a reduced-scale illustration of the first three weeks of printed output for assumed existing policies, and Figure 26 is a reduced-scale illustration of the plotted output for the total simulation period for assumed existing policies of Model B.

In Model A, a number of growth variables were tabulated and plotted. The variables of primary interest were book net worth (NW) and

PAGE 22 1

TIME	CC	MPR	MIP1	MLP1G	FPAS	PS	P1EQL	FLQ	P1L	CASH	NW
	OIR	MIS	MIP2	MLP2G	SR	PAD	P2EQL	EFL	P2L	PTD	MNW
	OB	MIR	MIP3	MLP3G			P3EQL	PLQ	P3L	FAI	
	OOR							TLR		FDL	
E+00	E+00	E+00	E+00	E+00	E+00	E+00	E+00	E+00	E+00	E+03	E+03
	E+00	E+00	E+00	E+00	E+00	E+00	E+00	E+00	E+00	E+03	E+03
	E+00	E+00	E+00	E+00			E+00	E+00	E+00	E+03	
	E+00							E+00		E+03	
.00	33.389	120.00	600.00	55.50	54.00	3.0000	2.0000	24.600	12.000	30.00	513.22
	75.00	120.00	540.00	70.56	54.00	3.0000	3.0000	24.600	12.000	100.0	472.1
	240.00	60.00	480.00	52.92			2.0000	2.4600	.6000	10.000	
	60.00							24.600		100.00	
1.00	33.696	100.00	600.00	53.37	52.92	3.0000	2.0000	23.985	11.539	49.65	513.38
	75.00	180.00	523.50	67.82	52.92	3.0000	3.0000	23.677	11.539	104.8	466.6
	255.00	60.00	496.56	52.92			2.0000	2.3370	.6000	29.647	
	60.00							24.600		119.62	
2.00	33.948	86.67	600.00	55.50	52.92	1.0000	2.0000	23.708	12.000	34.24	512.67
	75.00	220.00	504.87	54.00	52.92	1.0000	3.0000	23.093	10.319	109.5	453.3
	270.00	57.87	510.38	68.26			3.0000	2.2304	.7739	14.236	
	60.00							24.900		119.16	
3.00	34.374	76.36	600.00	46.57	68.26	2.0000	2.0000	23.741	10.069	53.84	513.15
	75.00	248.80	491.08	69.34	68.26	2.0000	3.0000	22.825	12.000	114.3	451.7
	285.00	59.83	510.38	65.95			3.0000	2.1423	.7552	33.845	
	57.87							24.900		138.70	
4.00	34.313	70.88	600.00	55.50	65.95	1.0000	2.0000	23.756	12.000	23.36	510.23
	75.00	265.33	482.21	68.04	65.95	1.0000	4.0000	22.697	10.127	119.2	440.1
	302.13	51.07	510.38	49.76			3.0000	2.0738	.5696	3.357	
	59.83							28.900		138.16	
5.00	33.969	61.38	600.00	45.16	49.76	3.0000	2.0000	25.863	9.765	22.89	506.54
	75.00	285.14	467.20	51.76	49.76	3.0000	4.0000	23.686	13.020	124.1	439.4
	317.31	59.28	510.38	78.63			3.0000	2.0204	.9000	2.893	
	51.07							28.900		137.63	
6.00	34.803	60.89	600.00	55.50	78.63	1.0000	2.0000	26.811	12.000	23.05	510.47
	75.00	287.24	442.80	80.13	78.63	1.0000	4.0000	24.602	11.931	128.7	438.9
	341.24	49.66	510.38	58.65			3.0000	2.0137	.6711	3.047	
	59.28							28.900		137.10	
7.00	34.563	54.12	600.00	55.50	58.65	1.0000	2.0000	27.237	12.000	23.69	504.16
	75.00	298.46	443.63	61.00	58.65	1.0000	4.0000	25.249	12.544	133.4	438.4
	356.96	59.16	510.38	61.68			3.0000	2.0242	.7056	3.686	
	49.66							28.900		136.58	
8.00	34.613	56.32	600.00	55.50	61.68	1.0000	2.0000	27.429	12.000	23.91	504.58
	75.00	293.42	416.80	63.41	61.68	1.0000	4.0000	25.658	12.931	138.2	438.9
	382.29	60.00	510.38	63.60			3.0000	2.0396	.7274	3.906	
	59.16							28.900		136.05	

Figure 23. The First Three Weeks of Printed Output for Model A

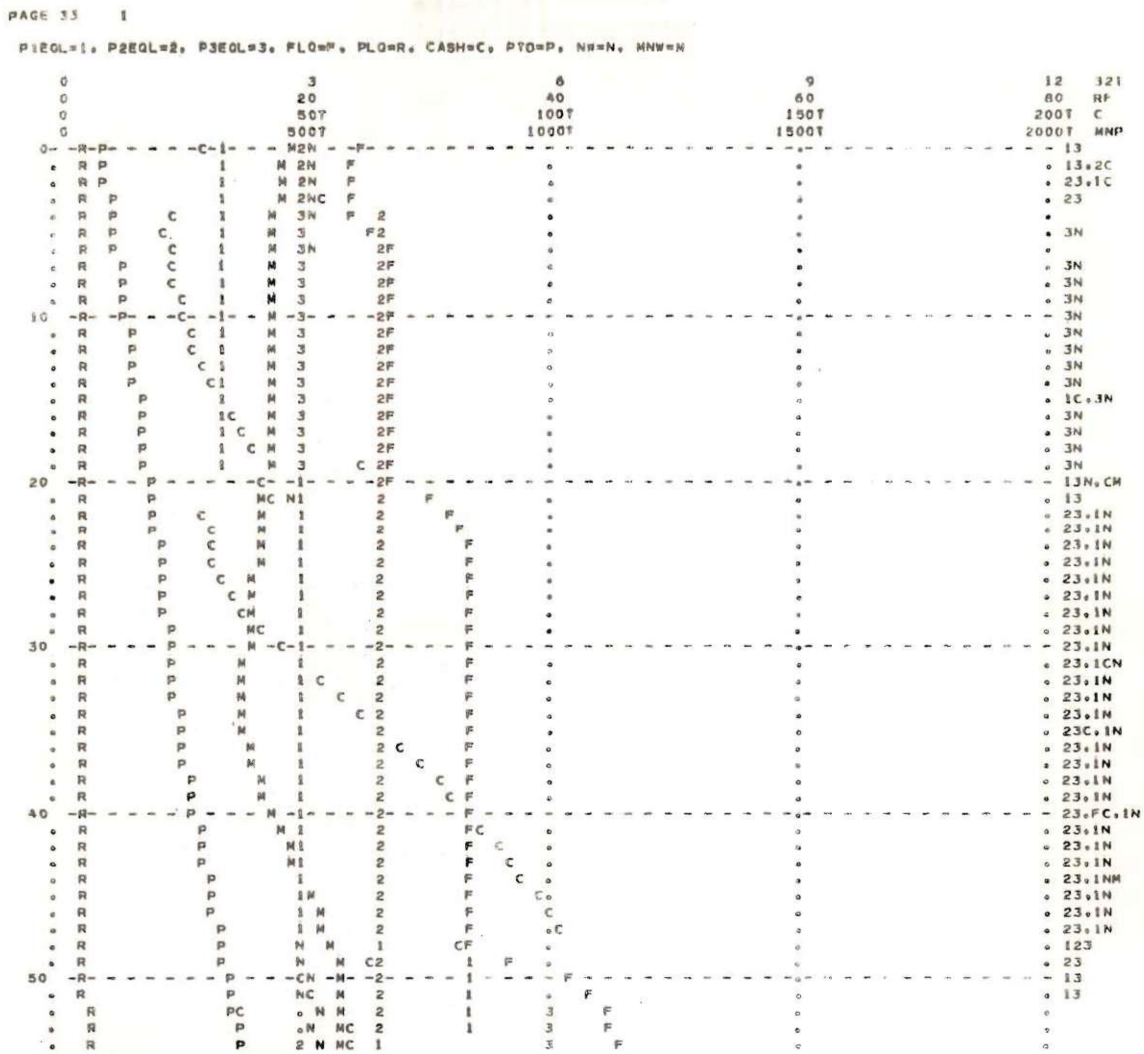


Figure 24. Plotted Output for Model A Employing Existing Policy

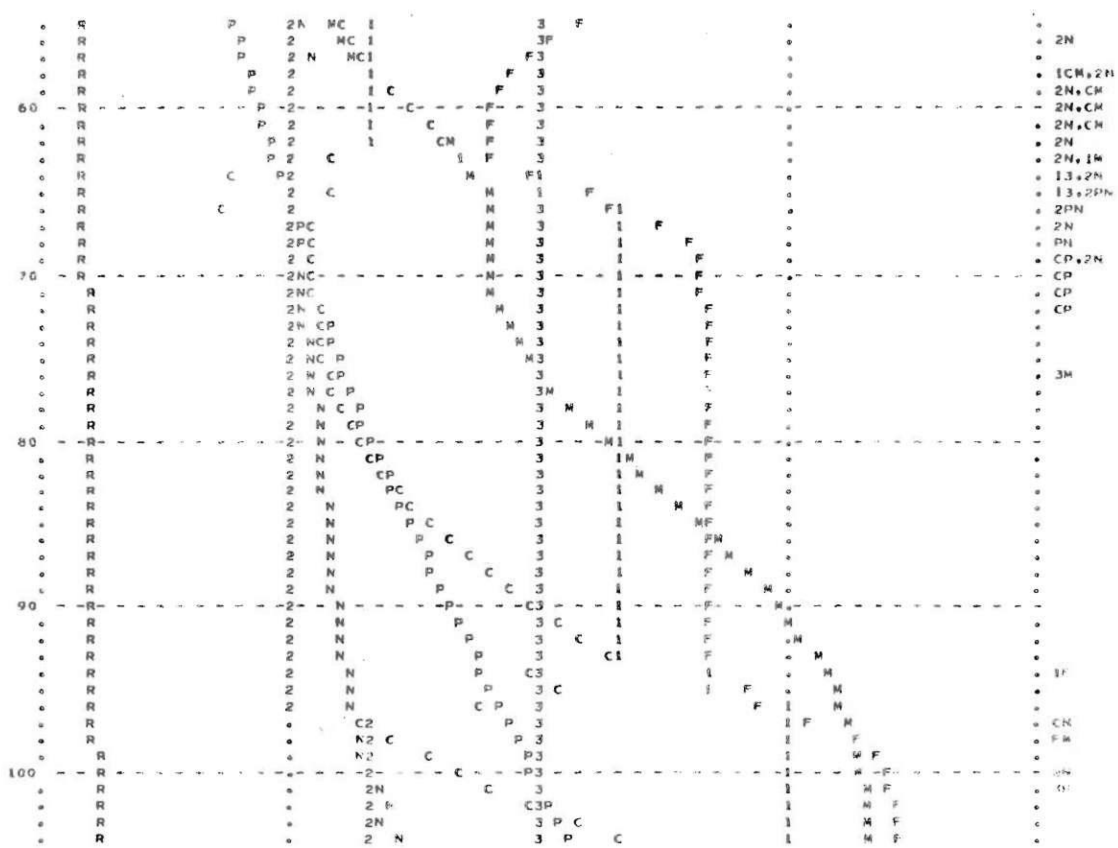


Figure 24. (Continued)

PAGE 11 1

TIME	LS	CMHR	CMHA	CMAR	CHARP	CQ	FLQ	PCMG	NCMG	WDCMG	AC	OS	FWG	CNP
	HS	TMHR	TMHA	TMAR	TMARP	TQ	MLQ	ICMG	GICMG	FC	AD	FD	MBPX	
	PS	UMHR	UMHA	UMAR	UMARP	UQ	GSOP2	CCMG	UCMG	IA	NR	MC		
	SS	HMHR	HMHA	HMAR	HMARP	HQ	PLOP2	KCMG	RCMG	CX	AI	IX		
	MS	VMHR	VMHA	VMAR	VMARP	VQ	FWCMG	BCMG	MICMG	PT	DS	MOX		
	RS	PMHR	PMHA	PMAR	PMARP	PQ	MBP	LCMG	LACMG	MP	LG	CI		
	TMS						MEDV	SCMG	MRCMG	MGI	TT	MOI		
	TS						AUTBV	PTCMG	MDCMG	TV	TL	NP		
E+00	E+03	E+00	E+00	E+00	E+00	E+00	E+00	E+03	E+00	E+00	E+00	E+00	E+03	E+03
	E+00	E+00	E+00	E+00	E+00	E+00	E+00	E+00	E+00	E+00	E+00	E+00	E+03	
	E+03	E+00	E+00	E+00	E+00	E+00	E+00	E+00	E+00	E+03	E+00	E+00		
	E+00	E+00	E+00	E+00	E+00	E+00	E+00	E+00	E+00	E+00	E+00	E+00		
	E+00	E+00	E+00	E+00	E+00	E+00	E+00	E+00	E+00	E+00	E+00	E+00		
	E+00	E+00	E+00	E+00	E+00	E+00	E+00	E+00	E+00	E+00	E+00	E+00		
	E+03						E+03	E+00	E+00	E+00	E+00	E+00		
	E+03						E+00	E+00	E+00	E+00	E+00	E+00		
.000	18.526	335.84	300.00	1.1195	1.8000	2.0000	12.000	14.083	.00	34.242	75.28	131.47	.00	.107
	1971.8	186.93	160.CC	1.1683	3.0000	1.0000	3.0000	3096.2	188.53	1368.6	.00	30.838	.00	
	4.147	50.61	170.CC	.2977	2.0000	1.0000	.0	152.34	476.82	3.196	.000	.00		
	.0	49.52	170.00	.2913	2.0000	1.0000	0.	339.9	943.58	273.4	.000	573.5		
	.00	67.17	160.00	.41979	2.0000	1.0000	2902.6	.00	66.31	82.58	16.380	60.654		
	3396.0	64.77	150.00	.4318	2.0000	1.0000	1815.8	.00	70.20	.00	137.88	148.40		
	24.644						59.71	196.66	204.35	117.46	432.22	.00		
	28.040						.0	167.91	615.5	738.5	106.27	-4506.4		
1.000	19.364	351.53	300.00	1.1718	1.8000	2.0000	10.980	14.775	.00	34.607	84.19	138.81	2.90	-4.399
	2095.8	195.66	160.00	1.2229	3.0000	1.0000	3.9604	3237.4	181.99	1464.0	.00	31.692	1.82	
	4.705	53.79	170.00	.3164	2.0000	1.0000	.0	154.48	485.11	3.186	.000	.00		
	.0	52.63	170.00	.3096	2.0000	1.0000	0.	362.8	944.44	314.4	.000	564.7		
	.00	70.31	160.00	.43942	2.0000	1.0000	2682.0	.00	65.60	95.08	16.954	60.851		
	3385.9	73.47	150.00	.4898	2.0000	1.0000	2397.2	.00	69.84	.00	143.13	151.50		
	26.165						59.25	202.95	200.00	128.18	441.46	.00		
	29.550						.0	160.58	616.4	750.3	112.00	-4399.6		
2.000	20.203	368.65	300.00	1.2288	1.8000	2.0000	10.064	15.466	.00	34.971	93.10	146.15	5.58	-8.799
	2219.8	205.19	160.00	1.2825	3.0000	1.0000	4.9081	3378.7	178.78	1559.3	.00	32.538	4.21	
	5.262	57.88	170.00	.3405	2.0000	1.0000	.0	156.62	493.39	3.176	.000	.00		
	.0	56.63	170.00	.3331	2.0000	1.0000	0.	385.7	945.31	355.4	.000	555.9		
	.00	73.73	160.00	.46082	2.0000	1.0000	2583.1	.00	64.90	107.75	17.528	61.047		
	3375.8	81.88	150.00	.5459	2.0000	1.0000	2986.1	.00	69.48	.00	148.39	154.60		
	27.685						58.79	209.24	195.63	139.04	450.70	.00		
	31.060						.0	157.30	617.3	762.0	117.72	-4429.8		
3.000	21.042	385.91	300.00	1.2864	1.8000	2.0000	9.242	16.157	.00	35.336	102.01	153.50	8.17	-13.229
	2343.8	214.80	160.00	1.3425	3.0000	1.0000	5.8433	3520.0	175.68	1654.7	.00	33.377	7.20	
	5.819	62.07	170.00	.3651	2.0000	1.0000	.0	158.76	501.68	3.166	.000	.00		
	.0	60.73	170.00	.3572	2.0000	1.0000	0.	408.6	946.18	396.3	.000	547.0		
	.00	77.18	160.00	.48239	2.0000	1.0000	2486.9	.00	64.19	120.38	18.102	61.243		
	3365.6	90.22	150.00	.6015	2.0000	1.0000	3573.3	.00	69.11	.00	153.64	157.71		
	29.205						58.33	215.54	191.26	149.86	459.94	.00		
	32.570						.0	154.11	618.3	773.8	123.44	-4461.0		

Figure 25. The First Three Weeks of Printed Ouput for Model B

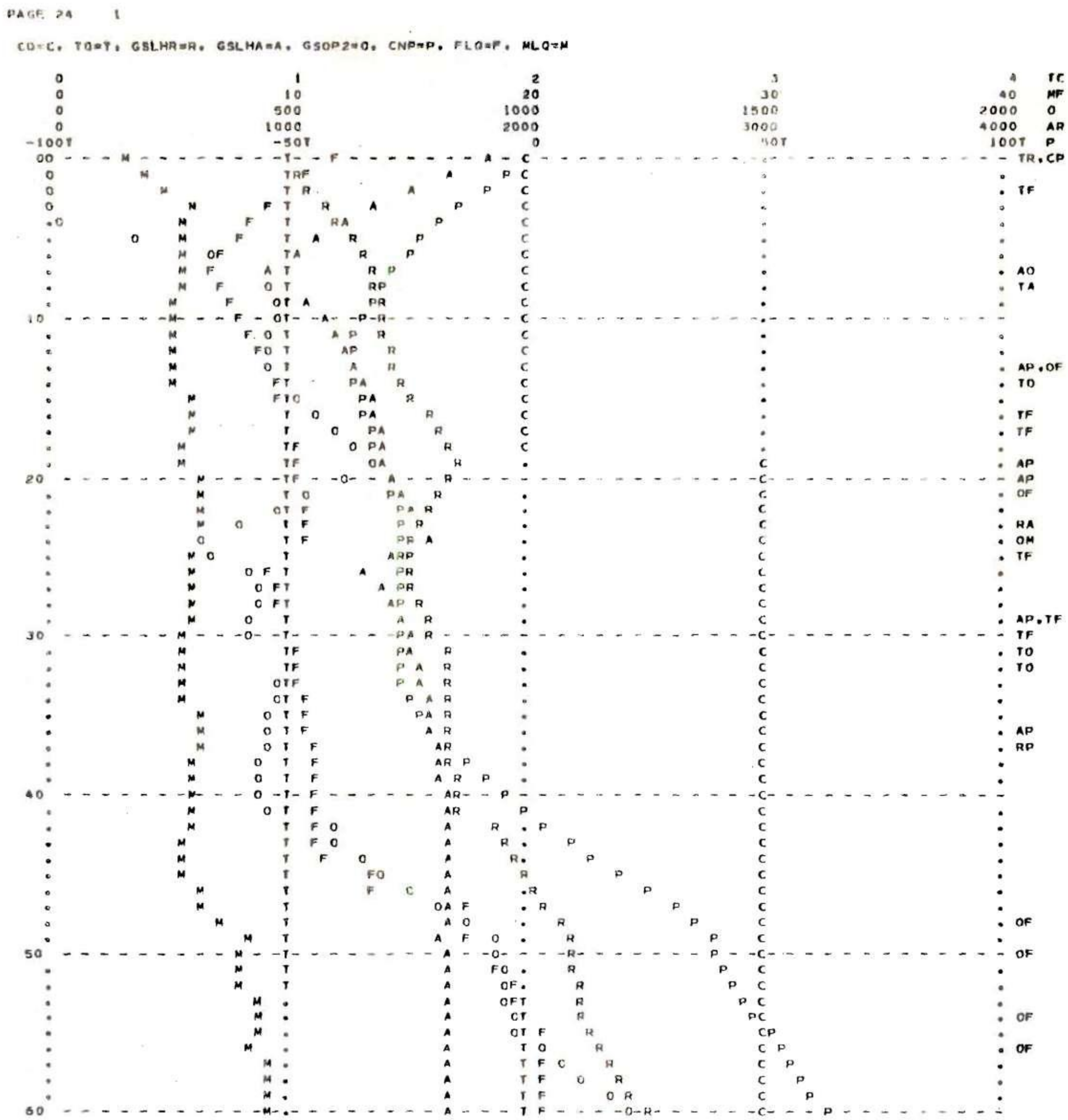


Figure 26. Plotted Output for Model B

Employing Policy I

market net worth (MNW); however, variables such as order input rate (OIR), processes one, two and three equipment quantity levels (P1EQL, P2EQL and P3EQL), and the factory labor quantity (FLQ) also were considered.

In all instances, the initial levels of all variables for all policies considered relative to Model A are identical. Therefore, growth generated by each policy employed can be measured against the same initial base level for each variable. Table 2 indicates the initial level of each variable of interest in Model A.

Table 2. Initial Levels of Selected Variables in Model A

Variable	Initial Value
Book Net Worth (NW)	\$513,000
Market Net Worth (MNW)	\$472,100
Process 1 Equipment Quantity Level (P1EQL)	2
Process 2 Equipment Quantity Level (P2EQL)	3
Process 3 Equipment Quantity Level (P3EQL)	2
Order Input Rate (OIR)	75
Factory Labor Quantity (FLQ)	24.6

In all instances, Model B variables of interest also have identical initial values for all policies employed. Therefore, growth as a function of the policies employed can be considered in relation to common initial base levels. Since Model B is limited to simulation of profit generation, as compared to net worth generation in Model A, the variables of interest in Model B are cumulative net profit (CNP), machine C quantity (CA), machine T quantity (TQ), machine U quantity (UQ), machine H quantity (HQ), machine V quantity (VQ), machine P quantity (PQ), and factory labor quantity (FLQ). Table 3 indicates the initial level of each variable of interest in Model B.

Table 3. Initial Levels of Selected Variables in Model B

Variable	Initial Value
Cumulative Net Profit (CNP)	$107
Machine C Quantity (CQ)	2
Machine T Quantity (TQ)	1
Machine U Quantity (UQ)	1
Machine H Quantity (HQ)	1
Machine V Quantity (VQ)	1
Machine P Quantity (PQ)	1
Factory Labor Quantity (FLQ)	12

Figure 24 illustrates the general path of growth of the hypothetical company. As shown in Figure 24, an additional unit of process three equipment was added in the second week, a unit of process two equipment was added in the fourth week, and then equipment levels remained constant until the twentieth week. As indicated in Figure 23, the process acquisition desired index (PAD) in the first week was three; therefore, a unit of process equipment was added to process three in the following week, since sufficient funds were available for purchase of the process unit.

It can also be noted in Figure 24 that the factory labor level is a function of the process capacity. Factory labor quantity (FLQ) increased after addition of process equipment, as indicated in weeks 5 and 21. In the 54th week a unit of process two equipment was retired; this reduction in process equipment capacity caused a reduction in the factory labor quantity (FLQ) in the following months which was accomplished by normal attrition and the failure to hire replacement labor.

The cash level (CASH), in Figure 24, tended to build up gradually and then decay rapidly as an additional unit of equipment was purchased. In weeks 30 to 47, however, the cash level more than exceeded the required levels for purchase of additional equipment. However, examination of the printed output indicated that although process selected (PS) was equal to one, the process acquisition desired index (PAD) was equal to zero for weeks 30 to 46 inclusive. This indicates that although cash was available for investment, the order input rate (OIR) relative to present process capacity was insufficient to warrant purchase of an additional processing equipment unit, which was a formulated consideration contained in equation A98.

Regarding the primary variables of interest in Model A, Figure 24 indicates that book net worth (NW) remained essentially constant until the 67th week and then rose slightly to a final value approximately 50 per cent greater than its initial value. The market net worth (MNW), however, gradually decreased initially to a minimum in the 33rd week, and then rose to a peak in the 104th week approximately three times its initial level.

Figure 26, in a similar manner, illustrates the path of growth of the ABC Manufacturing Company. The actual initial equipment levels were as indicated for time zero in Figure 26. Final equipment levels were also in agreement with actual ABC Company information. During the 60-month simulation period, one additional machine C and one additional machine T were acquired. The actual additional machine C and machine T were added during months 19 and 58, respectively. In the existing policy simulation, an additional unit each of machine C and machine T were added in months 19 and 53, respectively.

In Figure 26, factory labor quantity (FLQ) declined initially to a minimum level of 6.7 in the seventh week and rose gradually until the 24th week, at which time it dropped slightly and then continued to rise throughout the remainder of the simulation period. Table 4 is a comparison of actual and simulated labor growth for the 60-month period.

Of particular interest with respect to Model B were the relative values of actual and simulated cumulative net profit (CNP) for the 60-month period. Actual cumulative net profit for the ABC Company at the end of the simulation period was $68,094, whereas the simulated cumulative net profit (CNP) was $63,212.

Table 4. A Comparison of Actual and Simulated Factory Labor Growth

Month	Actual	Simulated	Month	Actual	Simulated	Month	Actual	Simulated
1	12	10.9	21	12	10.7	41	13	11.3
2	11	10.1	22	11	10.8	42	13	11.3
3	10	9.2	23	12	10.9	43	13	11.4
4	9	8.5	24	11	11.0	44	13	11.4
5	10	7.8	25	10	10.1	45	15	13.5
6	9	7.2	26	10	9.2	46	15	13.5
7	9	6.7	27	11	9.5	47	19	17.5
8	9	7.2	28	12	9.7	48	20	17.5
9	9	7.7	29	11	10.0	49	18	17.6
10	11	8.1	30	11	10.1	50	21	18.6
11	10	8.5	31	11	10.3	51	21	18.6
12	11	8.8	32	11	10.5	52	22	19.6
13	12	9.1	33	13	10.6	53	22	19.6
14	11	9.4	34	13	10.7	54	26	19.7
15	12	9.6	35	12	10.8	55	24	20.7
16	12	9.8	36	13	10.9	56	24	20.7
17	11	10.1	37	12	11.0	57	25	20.7
18	11	10.2	38	13	11.1	58	29	20.7
19	12	10.4	39	13	11.2	59	27	20.7
20	13	10.5	40	13	11.2	60	24	20.7

Revised Policy Results

Policy 1 Simulation Results

Policy 1, as described in the previous chapter, represents a revised depreciation policy for Model A. Under existing policy, the straight-line depreciation method was employed, whereas Policy 1 employed the double-declining balance method of depreciation.

Figure 27 is an illustration of the plotted output for Policy 1. The change in depreciation method produced only slight changes in company growth during the simulation period. Table 5 is a comparison of existing and Policy 1 final values for selected growth variables.

The variable which indicated the greatest change was book net worth. Book net worth (NW) decreased slightly under Policy 1 as compared to existing policy.

Table 5. A Comparison of Final Values of Selected Growth Variables for Existing Policy and Policy 1

Variable	Existing Policy	Policy 1
Book Net Worth (NW)	$ 714,690	$ 682,260
Market Net Worth (MNW)	$1,663,100	$1,637,900
Process 1 Equipment Quantity Level (P1EQL)	9	9
Process 2 Equipment Quantity Level (P2EQL)	4	4
Process 3 Equipment Quantity Level (P3EQL)	6	6
Order Input Rate (OIR)	224	224
Factory Labor Quantity (FLQ)	68.5	68.5

Policy 2 Simulation Results

The basic assumption underlying Policy 2 was that the management of the hypothetical company had limited investment to internally generated

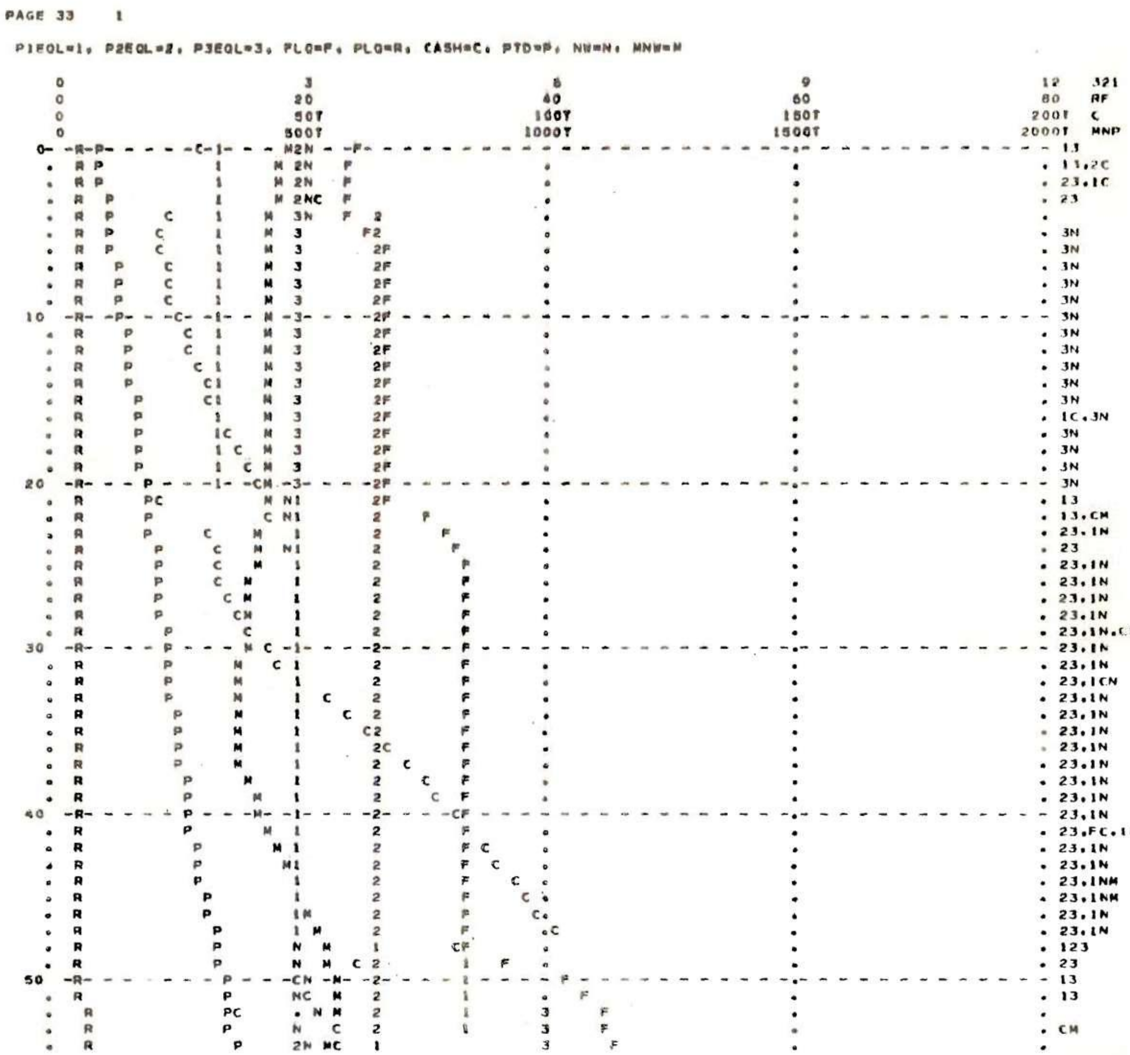


Figure 27. Plotted Output for Model A

Employing Policy 1

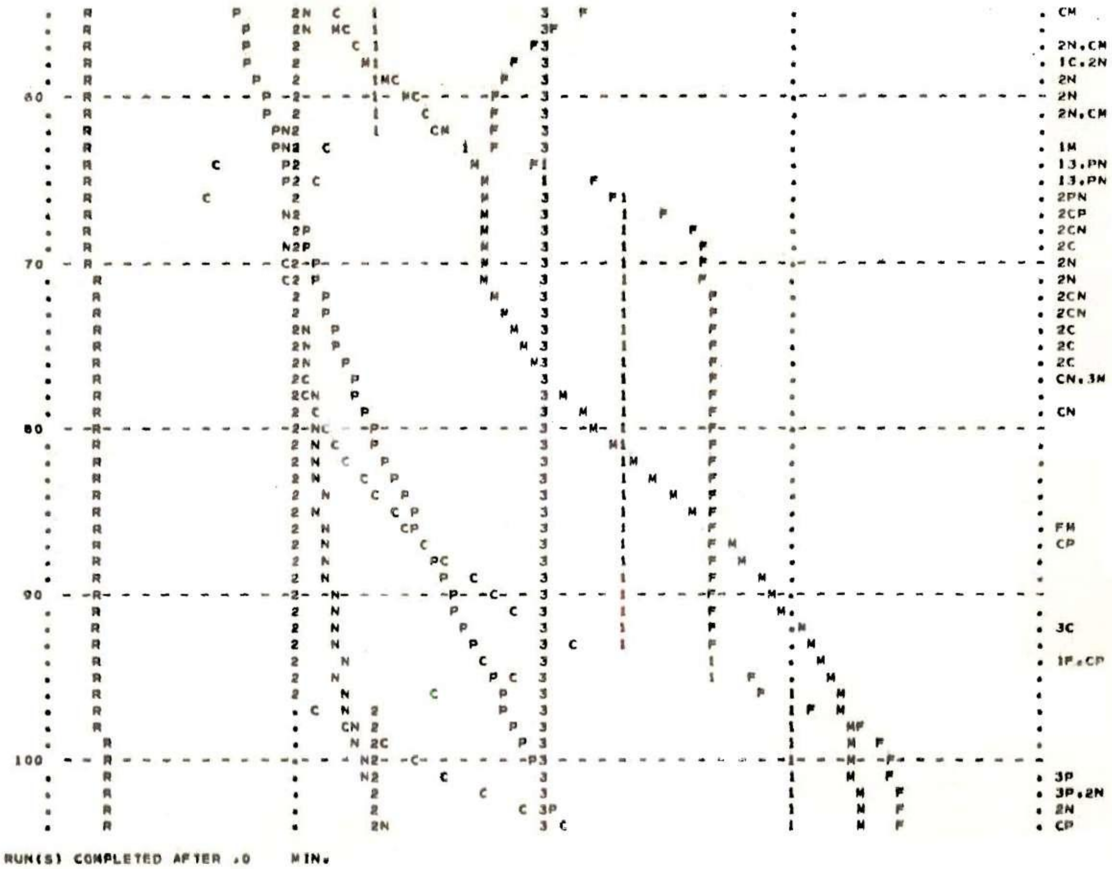


Figure 27. (Continued)

funds. Therefore, outside funds were not acquired during the simulation period to finance growth, regardless of the debt-equity level, applicable interest rate, or profit history of the company.

Figure 28 is an illustration of the plotted output for Policy 2. It should first be noted that scales of plotted variables were reduced considerably for Policy 2 as compared to those employed for existing policy. Therefore, overall comparison can best be made by comparing final values of selected growth variables for Policy 2 and existing policy, as indicated in Table 6.

Table 6. A Comparison of Final Values of Selected Growth Variables for Existing Policy and Policy 2

Variable	Existing Policy	Policy 2
Book Net Worth (NW)	$ 714,600	$467,930
Market Net Worth (MNW)	$1,663,100	$545,680
Process 1 Equipment Quantity Level (P1EQL)	9	5
Process 2 Equipment Quantity Level (P2EQL)	4	3
Process 3 Equipment Quantity Level (P3EQL)	6	4
Order Input Rate (OIR)	224	89
Factory Labor Quantity (FLQ)	68.5	38.1

It is apparent from Table 6 that the employment of Policy 2 resulted in a substantial effect on company growth, as compared to existing policy. Final values under Policy 2 were within the range of one-third to two-thirds of existing policy growth variable values.

It can be noted in Figure 28 that process capacity under Policy 2 remained constant for almost one-half of the total simulation period, and that cash declined to a level of approximately $15,000 in the 21st week

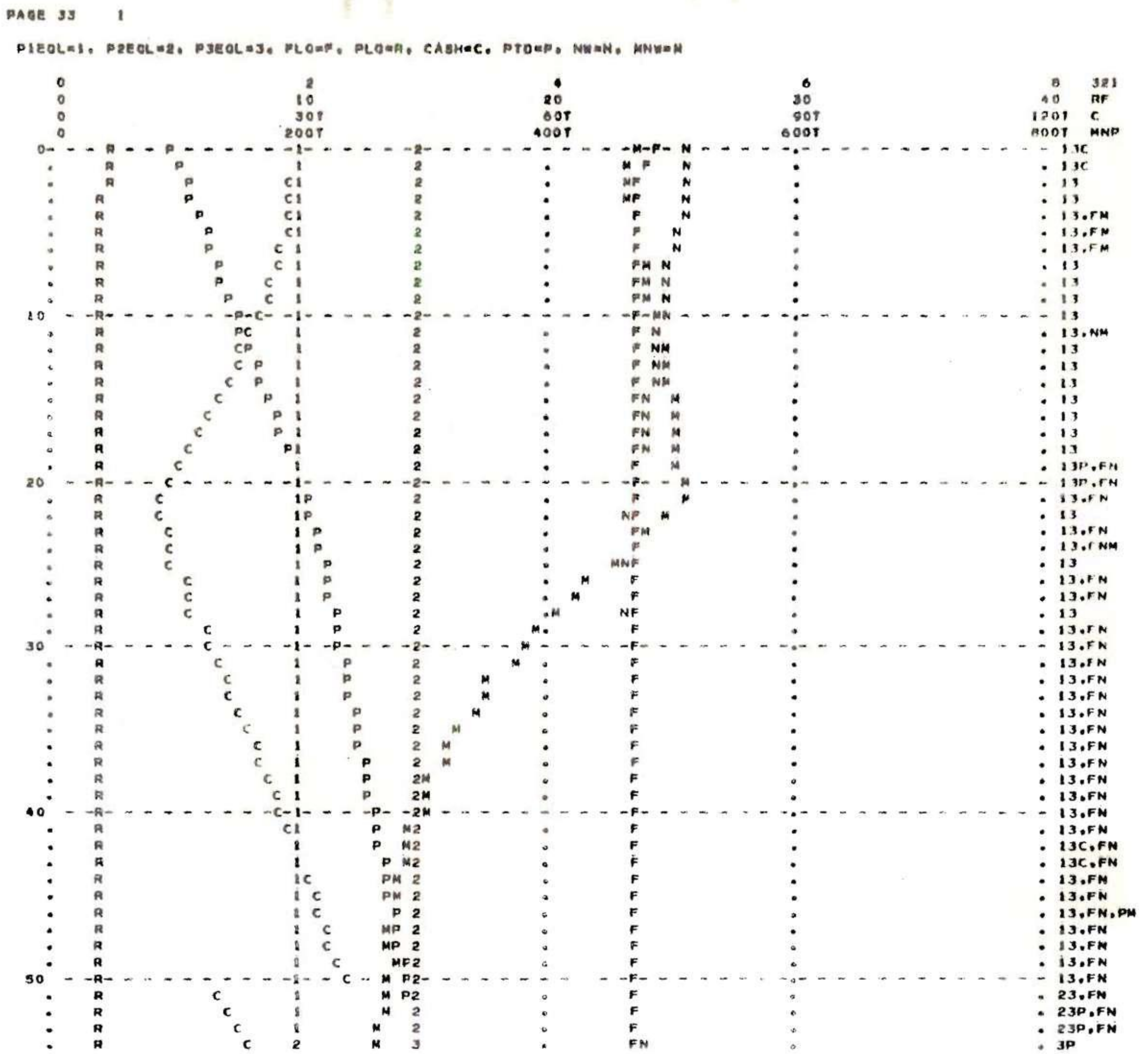
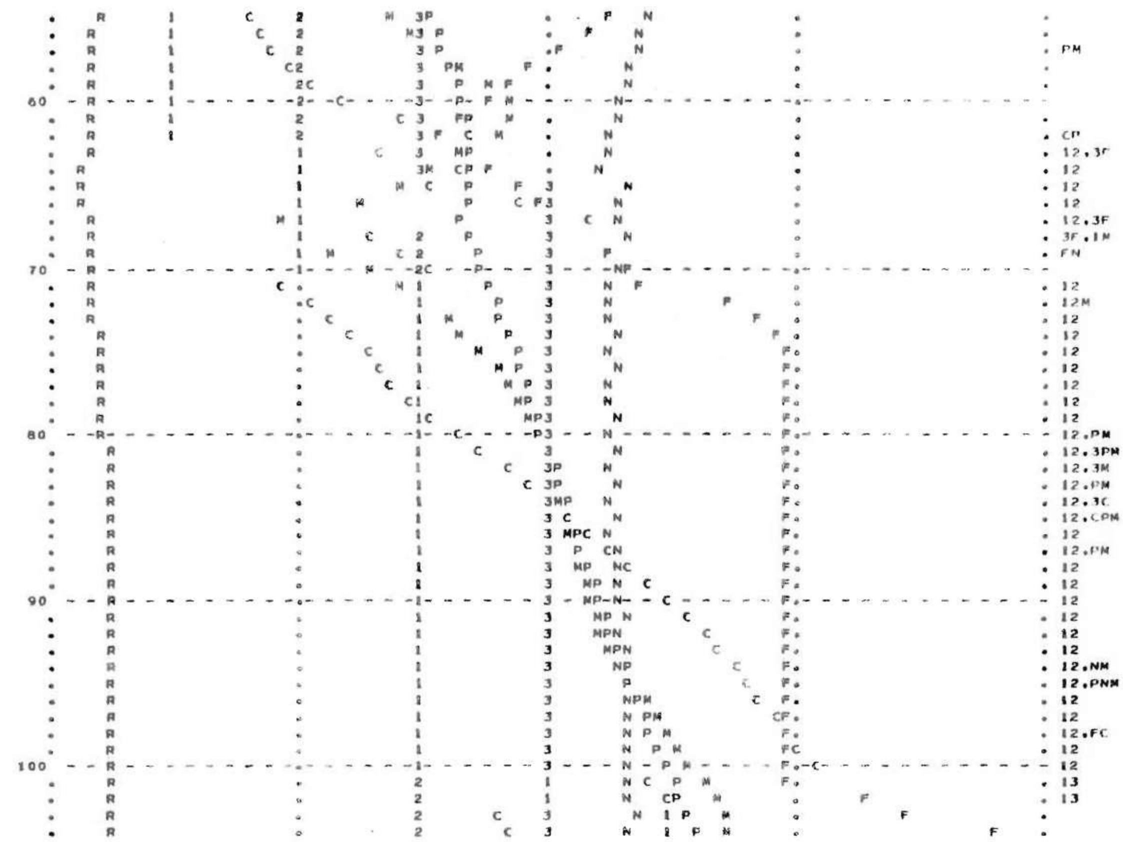


Figure 28. Plotted Output for Model A
Employing Policy 2



RUN(S) COMPLETED AFTER .0 MIN.

Figure 28. (Continued)

before recovering and eventually becoming sufficient in the 50th week to allow purchase of an additional process three unit of equipment.

Book net worth (NW) remained essentially constant throughout the simulation, ending with a final value of $467,930, which is slightly less than the book value of $513,000 at the beginning of the simulation period. Market net worth (MNW) rose somewhat from its initial value of $472,100 to a final value of $545,680.

Policy 3 Simulation Results

Policy 3 was an attempt to base the replacement decision for Model A on the minimum next-period cost of equipment operation rather than a minimum equipment reliability level as employed in the existing policy formulation.

Figure 29 is an illustration of the plotted output for Policy 3. Table 7 compares the final value of selected variables under both existing policy and Policy 3.

Table 7. A Comparison of Final Values of Selected Growth Variables for Existing Policy and Policy 3

Variable	Existing Policy	Policy 3
Book Net Worth (NW)	$ 714,690	$ 557,710
Market Net Worth (MNW)	$1,663,100	$1,169,900
Process 1 Equipment Quantity Level (P1EQL)	9	6
Process 2 Equipment Quantity Level (P2EQL)	4	4
Process 3 Equipment Quantity Level (P3EQL)	6	6
Order Input Rate (OIR)	224	186
Factory Labor Quantity (FLQ)	68.5	51.4

It is apparent from Table 7 that the Policy 3 formulation had a

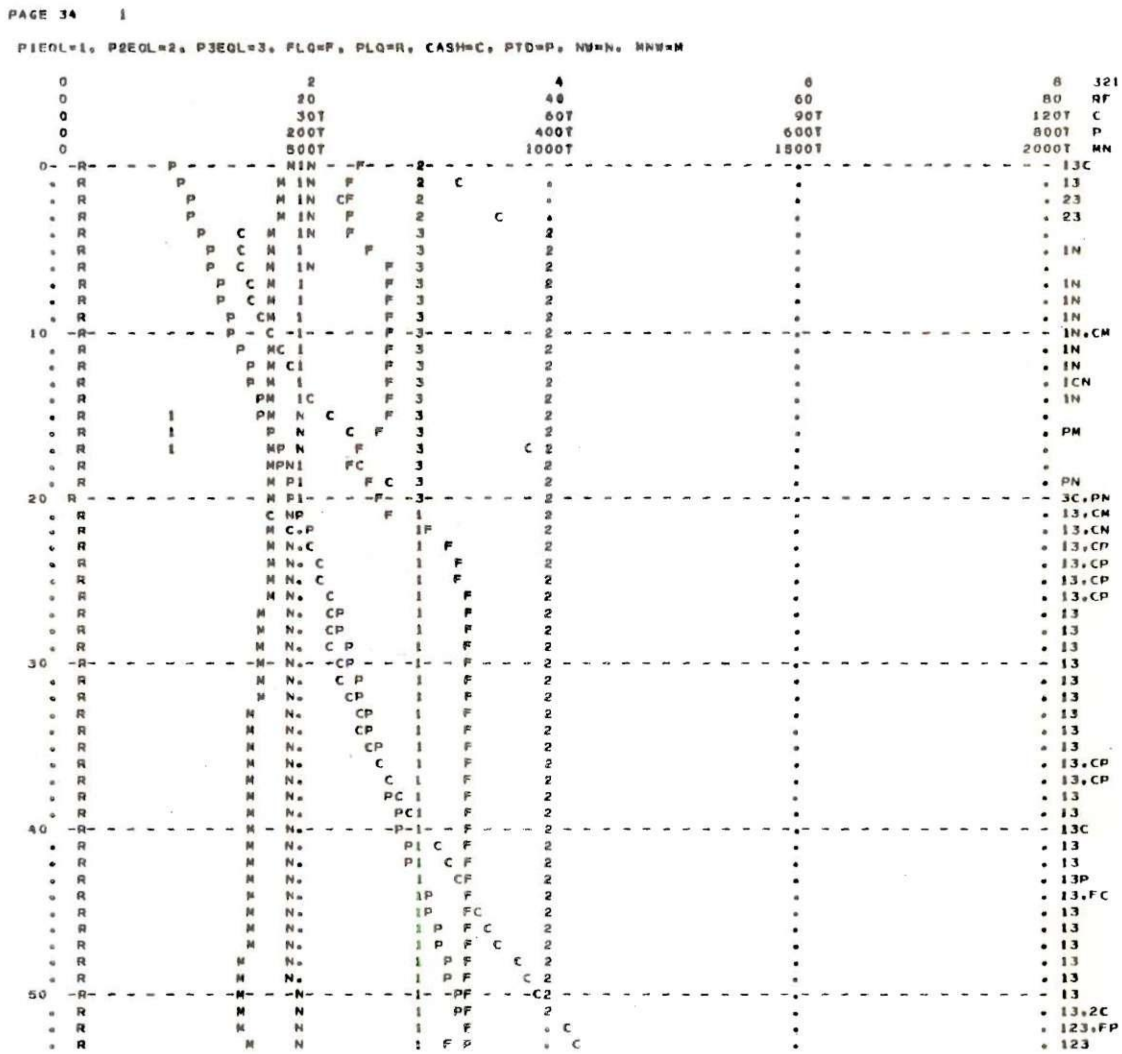
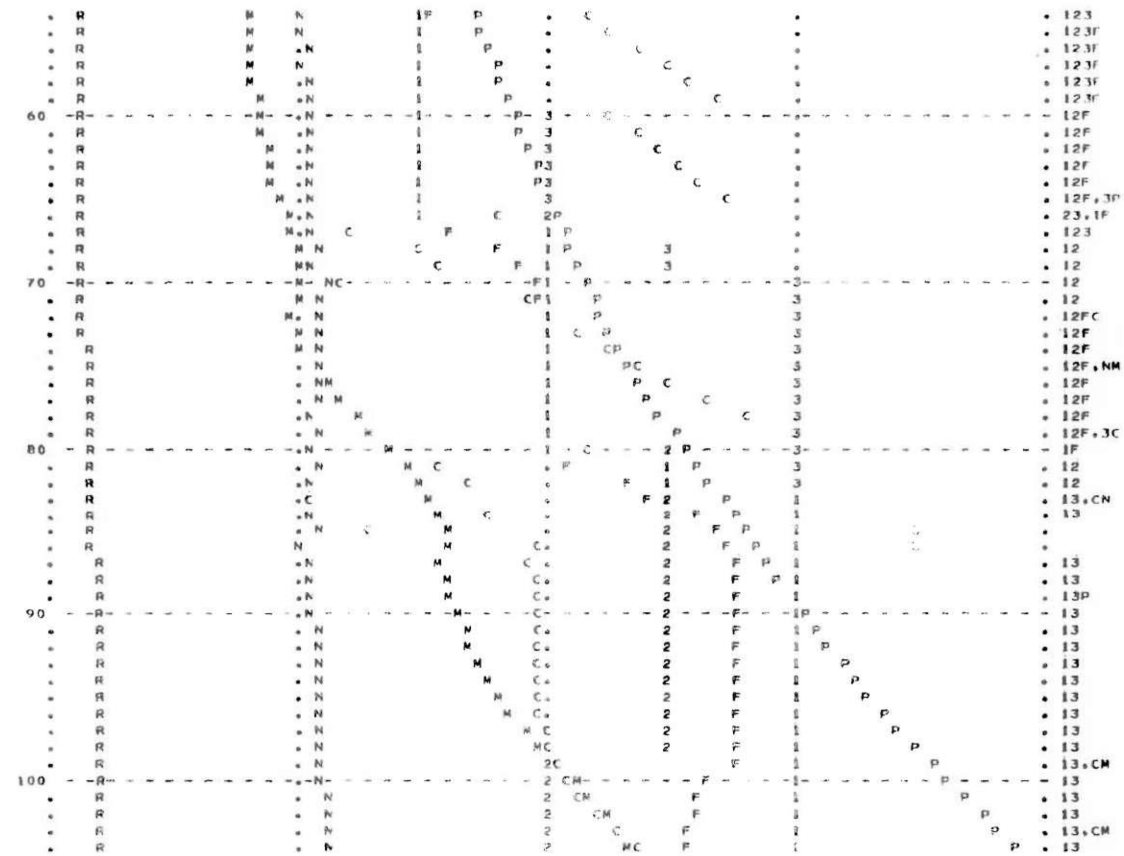


Figure 29. Plotted Output for Model A
Employing Policy 3



RUN(S) COMPLETED AFTER .0 MIN.

Figure 29. (Continued)

detrimental effect on company growth as compared to existing policy. Final values under Policy 3 are approximately two-thirds of the final values of such variables as book net worth (NW), market net worth (MNW), order input rate (OIR), and the factory labor quantity (FLQ.

In the 15th week, as indicated in Figure 29, a process one equipment unit was retired, reducing process one capacity to the output of the one remaining unit. In week 18 an additional process unit was acquired, and in week 21 another process one equipment unit was acquired.

Figure 29 indicates that book net worth under existing policy was essentially equivalent to that under Policy 3 up to and including the 77th week. However, book net worth rose more sharply for the remainder of the simulation period under existing policy than under Policy 3. Market net worth was nearly the same under both policies up to the 40th week, but for the remainder of the simulation period market net worth rose more rapidly under existing policy than under Policy 3.

Policy 4 Simulation Results

Policies 4A and 4B involved employing alternate constant values for the labor to equipment factor (LTEF), as compared to the 1.05 value employed under assumed existing policy. Policies 4A and 4B involved employing values of 1.00 and 1.10, respectively, in Model A.

Figures 30 and 31 are illustrations of plotted variables for Policies 4A and 4B, respectively. Table 8 compares final values for selected variables under existing policy and Policies 4A and 4B.

Existing policy resulted in both a higher book net worth (NW) and market net worth (MNW) than either of the revised policies. It may be noted that although Policy 4B results in setting a desired factory labor

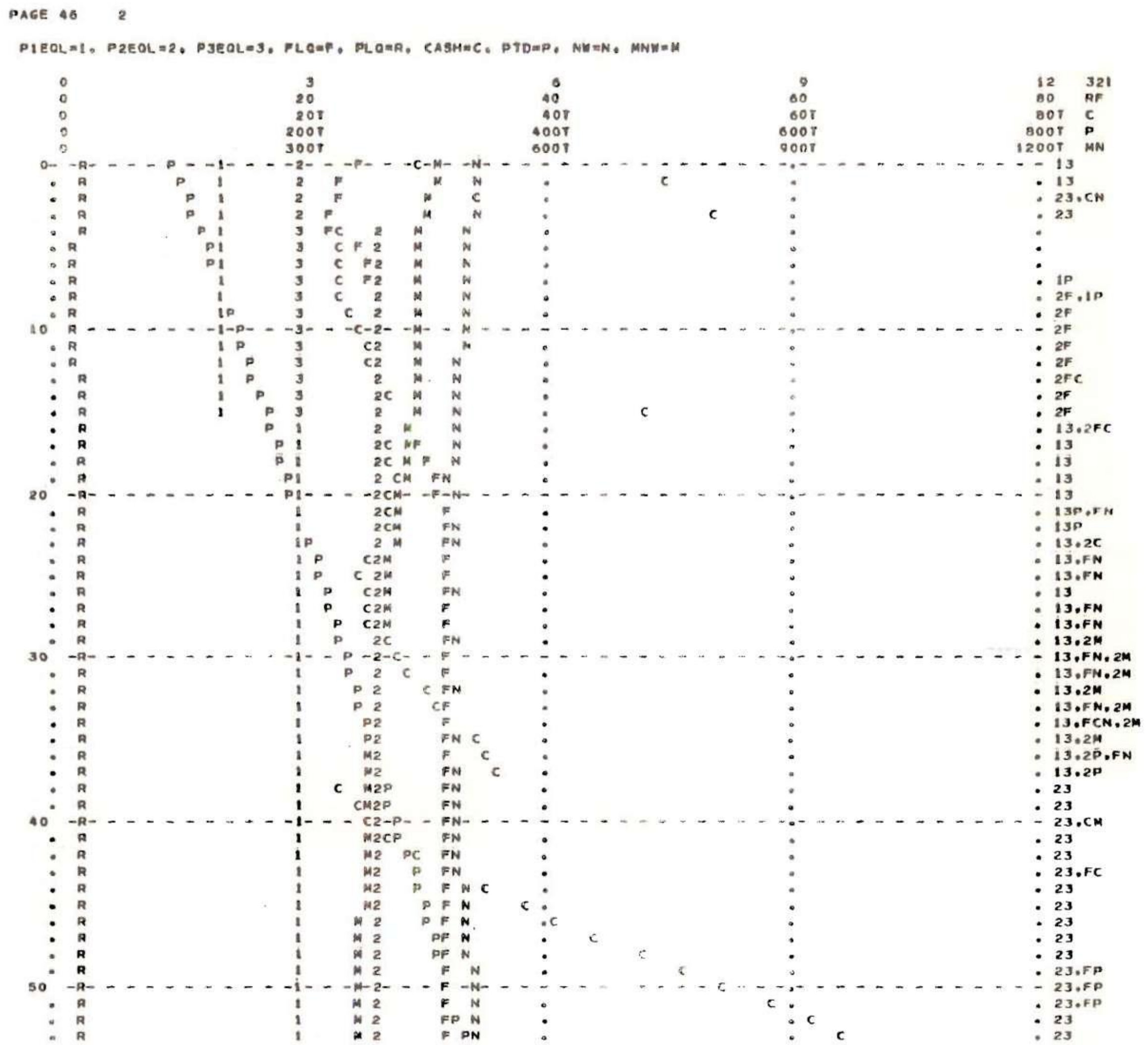


Figure 30. Plotted Output for Model A Employing Policy 4A

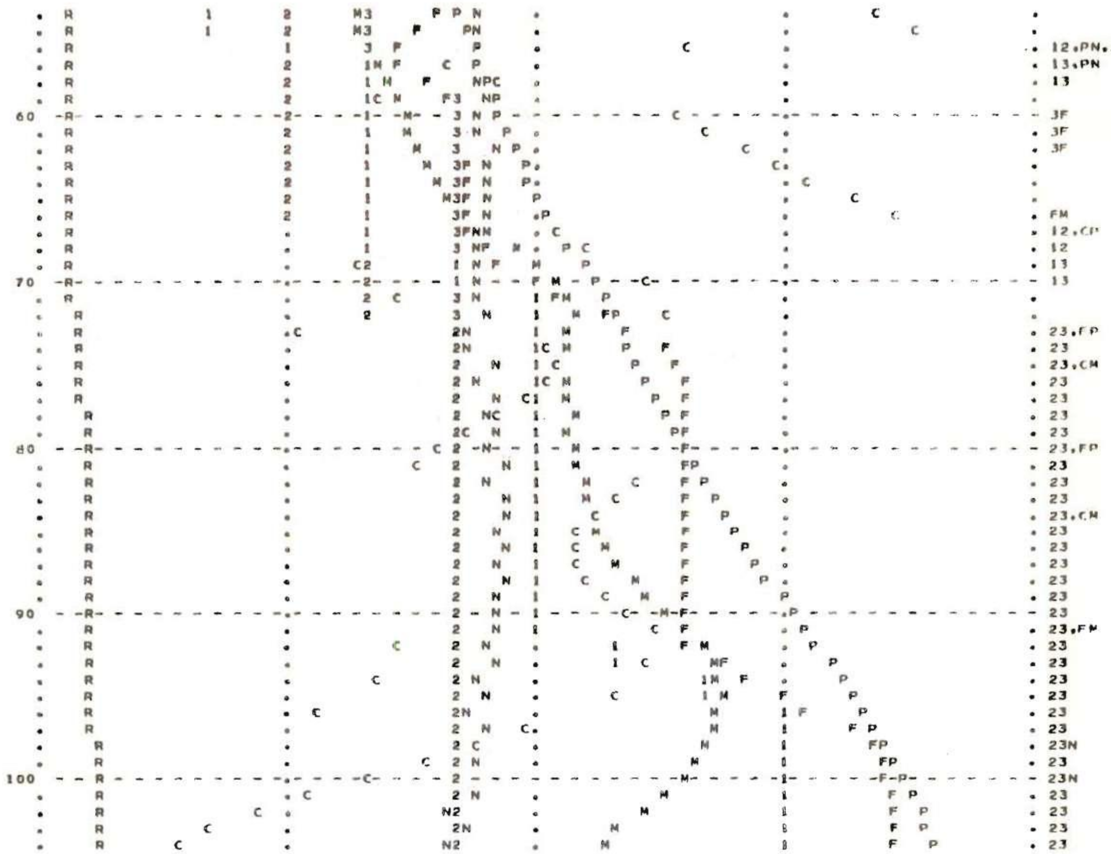


Figure 30. (Continued)

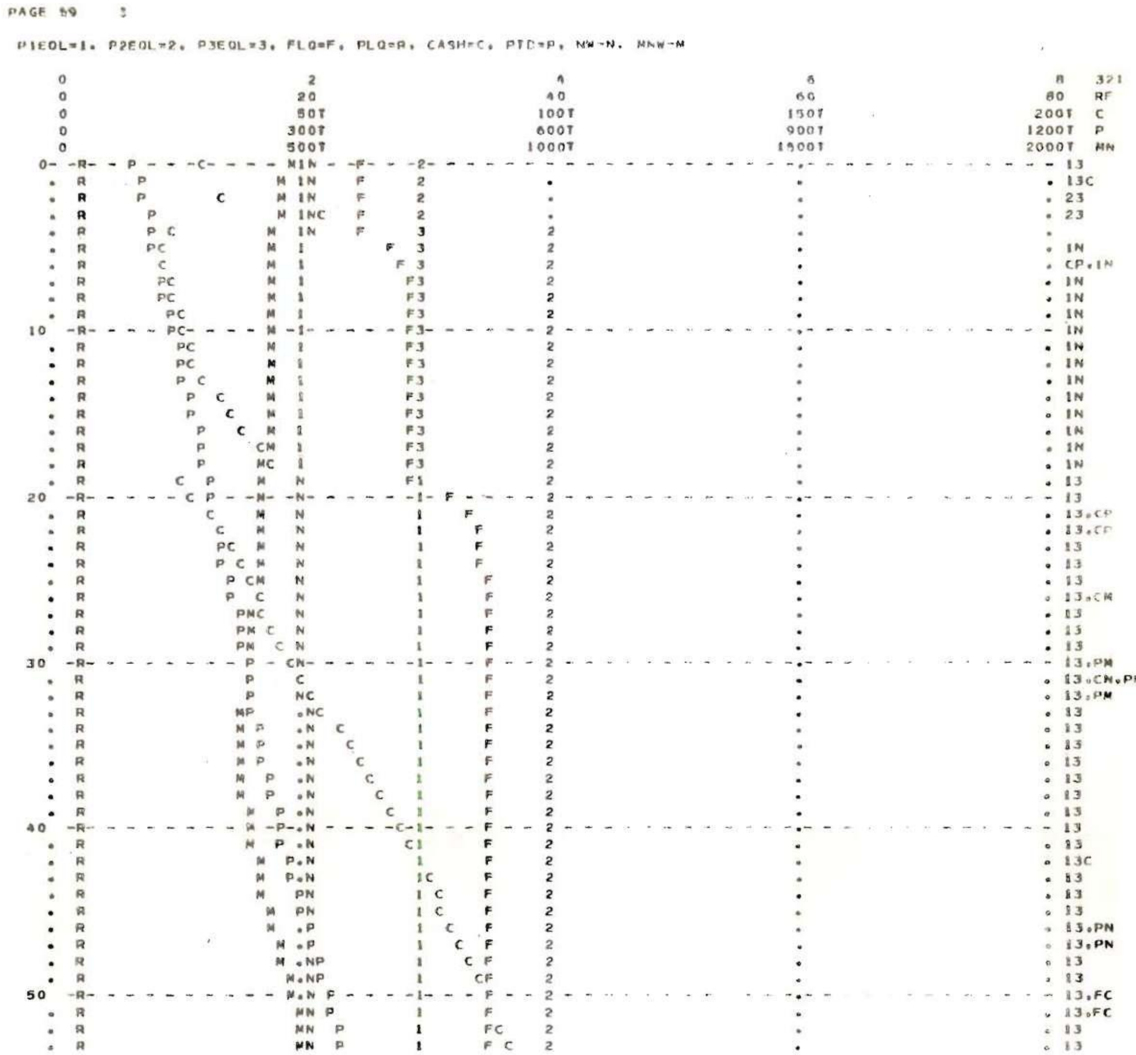
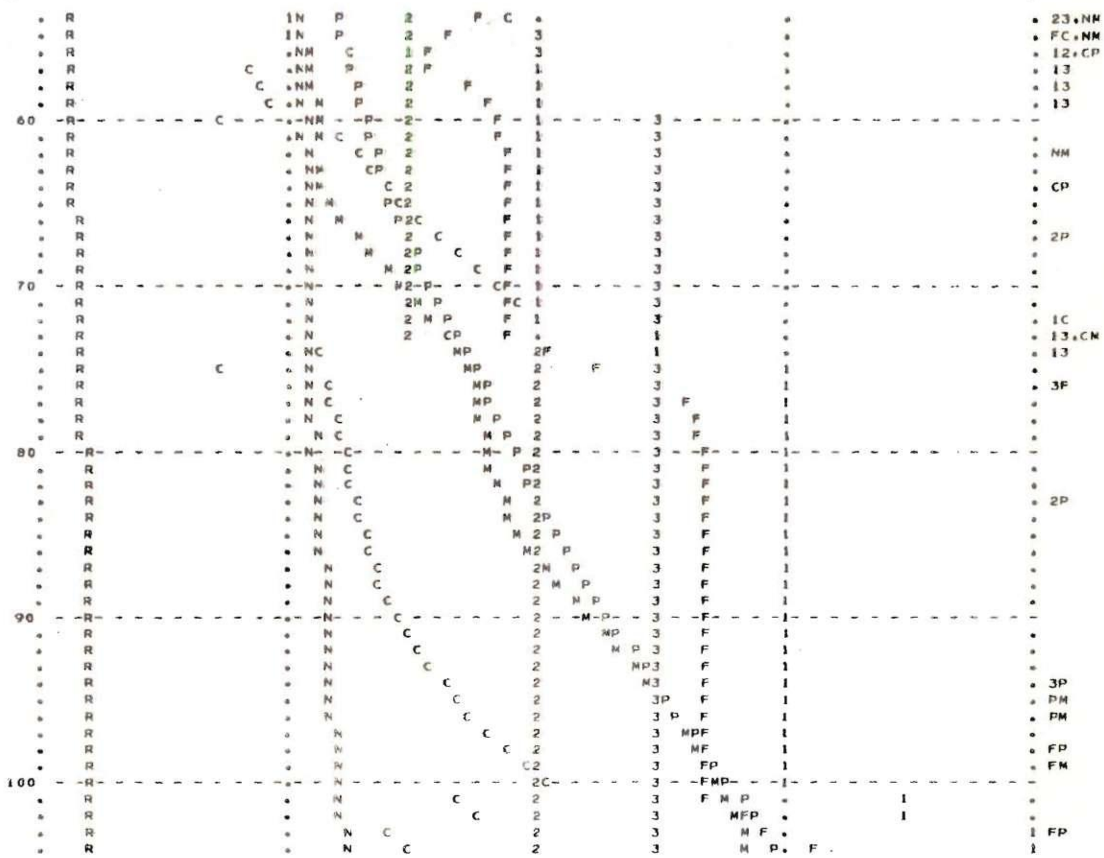


Figure 31. Plotted Output for Model A
Employing Policy 4B



RUN(S) COMPLETED AFTER .0 MIN.

Figure 3I. (Continued)

level 10 per cent higher than that specified under Policy 4A, the growth path of factory labor under both policies appears very similar in Figures 30 and 31. The factory labor quantity under Policy 4B, although increasing at approximately the same times as that under Policy 4A, is consistently slightly higher in value.

Table 8. A Comparison of Final Values of Selected Growth Variables for Existing Policy, Policy 4A, and Policy 4B

Variable	Existing Policy	Policy 4A	Policy 4B
Book Net Worth (NW)	$ 714,690	$494,370	$ 613,480
Market Net Worth (MNW)	$1,663,100	$678,450	$1,427,400
Process 1 Equipment Quantity Level (P1EQL)	9	9	8
Process 2 Equipment Quantity Level (P2EQL)	4	5	4
Process 3 Equipment Quantity Level (P3EQL)	6	5	5
Order Input Rate (OIR)	224	111	187
Factory Labor Quantity (FLQ)	68.5	68.6	62.3

Policy 5 Simulation Results

In Model B, Policy 5 was the first of two revised policies employed. Under existing policy, the actual overtime level was compared with an overtime policy level in the decision to hire additional factory labor. Policy 5 was developed to determine the relative effect of employing the hiring policy of Model A in Model B. The revised policy compares available factory labor with a constant factor times the amount of labor required for the quantity of equipment presently in use. Since the appropriate parameter values were unknown for maximizing growth variables, two reruns referred to as revised Policies 5B and 5C employed parameter valuses for both general and service labor, and process labor of 1.05 and 1.15, respectively.

Figure 32 is a reduced-scale illustration of the plotted output for Policy 5A. Table 9 compares selected growth variable final values of Policy 5 variables with existing policy values.

Table 9. A Comparison of Final Values of Selected Growth Variables for Existing Policy, Policy 5A, Policy 5B, and Policy 5C

Variable	Existing Policy	Policy 5A	Policy 5B	Policy 5C
Cumulative Net Profit (CNP)	$63,212	$57,727	$57,727	$57,727
Machine C Quantity (CQ)	3	3	3	3
Machine T Quantity (TQ)	2	2	2	2
Machine U Quantity (UQ)	1	1	1	1
Machine H Quantity (HQ)	1	1	1	1
Machine V Quantity (VQ)	1	1	1	1
Machine P Quantity (PQ)	1	1	1	1
Factory Labor Quantity (FLQ)	20.7	20.8	20.8	20.8

All Policy 5 simulations resulted in a lower cumulative net profit (CNP) as compared to existing policy at the end of the total simulation period. Of particular interest was the fact that all final output figures for Policies 5A, 5B and 5C were identical. The change in parameter values from 1.10 to 1.05 and 1.15 did not effect a change in simulation results. This result is considered in the next chapter.

Policy 6 Simulation Results

Policy 6 was employed to consider the effect on selected growth variables of delaying the purchase of an additional machine C. This change in policy was affected by increasing the machine C acquisition ratio policy (CMARP) from a value if 1.8 to 2.8. This change, in effect,

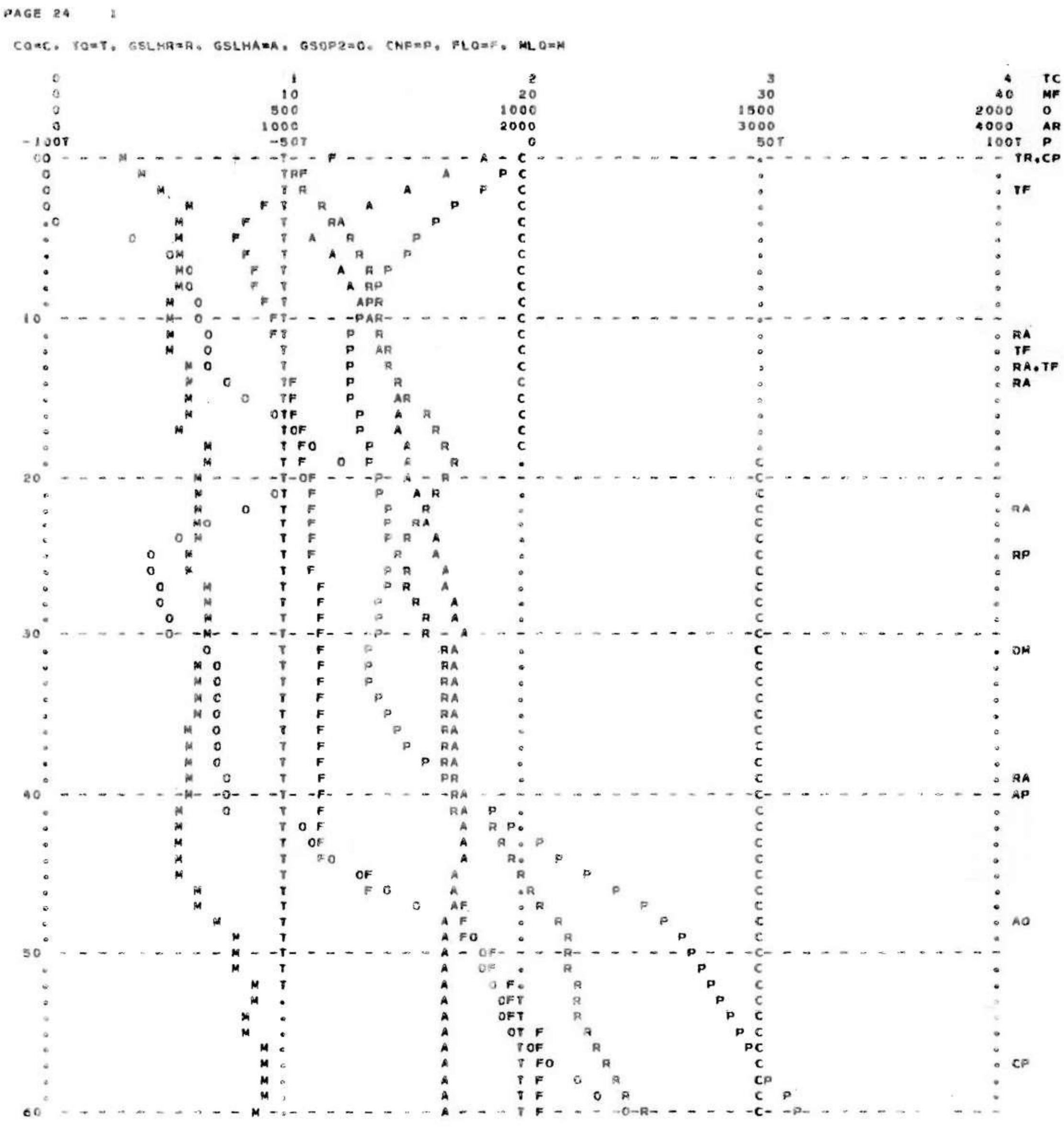


Figure 32. Plotted Output for Model B
Employing Policy 5A

assumes that an additional machine C is purchased when present machine C equipment is loaded in excess of 2.8 shifts.

Figure 33 is an illustration of plotted output for Policy 6. Table 10 is a comparison of final values of growth variables under existing policy and Policy 6.

Table 10. A Comparison of Final Values of Selected Growth Variables for Existing Policy and Policy 6

Variable	Existing Policy	Policy 6
Cumulative Net Profit (CNP)	$63,212	$119,320
Machine C Quantity (CQ)	3	2
Machine T Quantity (TQ)	2	2
Machine U Quantity (UQ)	1	1
Machine H Quantity (HQ)	1	1
Machine V Quantity (VQ)	1	1
Machine P Quantity (PQ)	1	1
Factory Labor Quantity (FLQ)	20.7	20.7

Cumulative net profit (CNP) at the end of the five-year simulation period, under Policy 6, was approximately twice what it was under existing policy. Under the revised policy, sufficient demand did not exist relative to machine C at the end of the simulation period to affect acquisition of an additional unit of machine C.

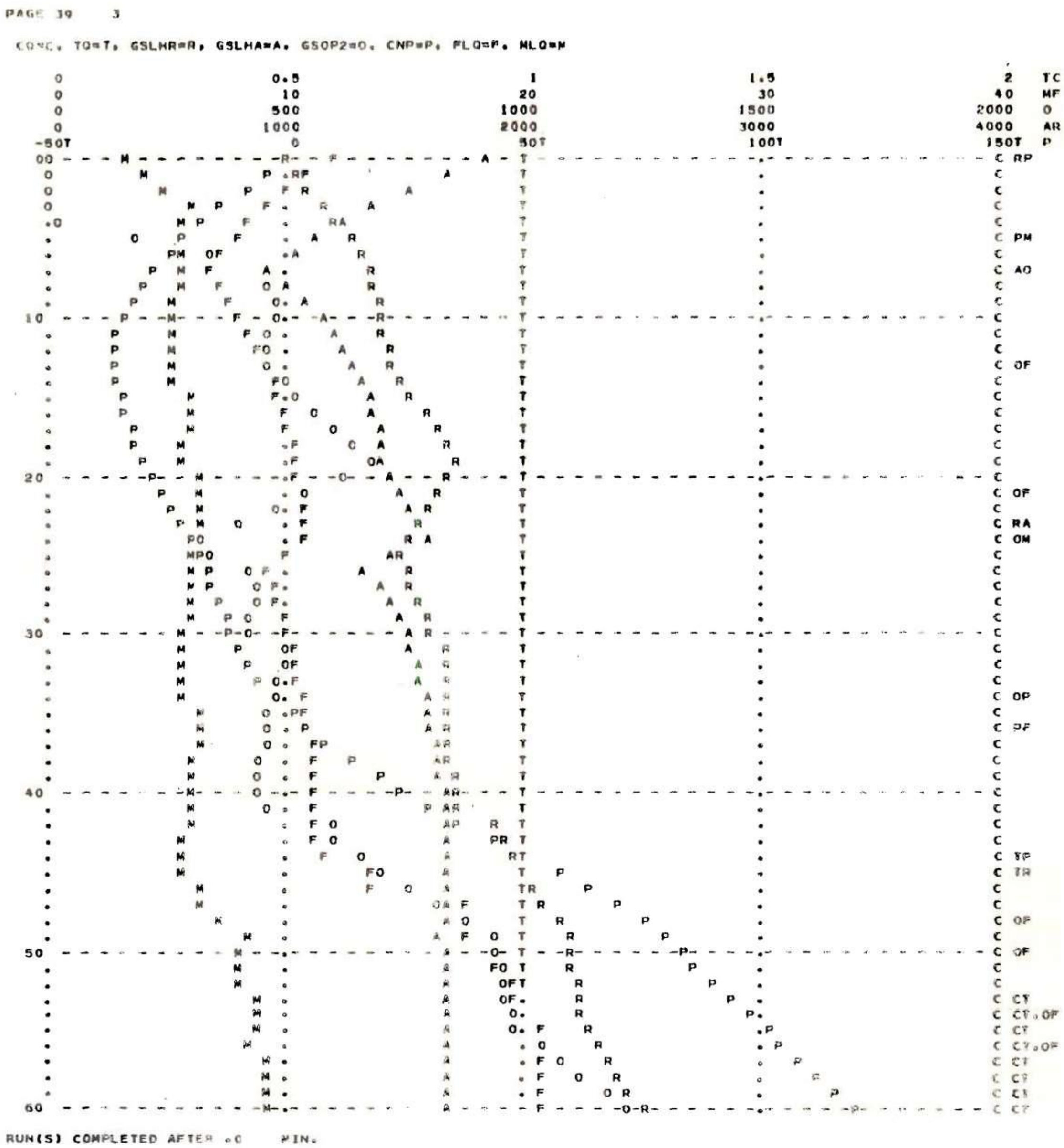


Figure 33. Plotted Output for Model B
Employing Policy 6

CHAPTER VI

CONCLUSIONS AND RECOMMENDATIONS

Conclusions

Since Model A was an industrial dynamics simulation of a hypothetical company, final values of variables could not be compared with actual values. Final values of variables and their trends, however, could be examined to determine whether they appeared mutually consistent. Since Model A contained a set of approximately 1,200 interrelated equations, successively computed 104 times, ample opportunity existed for an ill-founded or incomplete model formulation to produce illogical final values or trends of variables. All output produced for the policies employed, however, were both logical as to value and trend. No obviously undesirable data were generated which could serve to invalidate the general effectiveness of either the simulation system or model formulation. Unfortunately, however, neither could the results of Model A be validated by reference to known actual values for defined variables.

In the case of Model B, however, detailed records for five years of growth of the ABC Company were available to serve as a means of validating the absolute values of selected variables. Model B output did not offer evidence of variable values or trends of value which were inconsistent with the general nature of the growth experienced by the ABC Company. Since cumulative net profit (CNP) is a growth variable of considerable interest in economic system analysis and is dependent on effective model simulation in all sectors of the model for its value, its final simulated value as compared to the actual recorded historical value serves to provide some measure of the overall validity of both the model and the simulation system employed.

Actual cumulative net profit for the five-year period was $68,094, whereas simulated cumulative net profit was $63,212. Although this represents a difference of $4,782 between actual and simulated results, brief consideration of the means by which the value for this variable was generated leads to the conclusion that such a difference could reasonably have been expected. The cumulative net profit variable represents the successive addition of 60 individual period calculations for profit, in which each individual profit calculation represents the difference between all estimated revenues and costs for a given period. Therefore, because cumulative net profit represents the sum of 60 differences, the correspondence between actual and simulated cumulative net profit is considered good.

Table 4, which compares actual and simulated factory labor levels, indicates that the labor quantity generated by the model hiring policies resulted in labor levels somewhat less than actual. A smaller labor force employed to handle the same volume of product would result in additional overtime expenses which might account for the lower cumulative net profit.

Policy 1 results were contrary to what was expected. Accepted financial theory has demonstrated the financial growth advantage of accelerated depreciation as compared to straight-line depreciation. The tax-avoidance benefits of accelerated depreciation represent a definite growth advantage. Domar (7) states:

> That accelerated depreciation affords considerable tax relief to a new and growing firm can, I believe, safely be accepted, but how effective this relief will be in encouraging the organization and survival of new firms and in promoting growth in general is not easy to predict. Much will depend on the awareness of businessmen that the risk of investing in fixed capital is considerably reduced because no income tax need be paid until a substnatial part of the cost has been recovered; also on their understanding that such investment offers a perfectly legitimate method of tax avoidance, and on their readiness to consider these facts in their investment decisions (7, p. 212).

The simulation results indicated that both book net worth (NW) and market net worth (MNW) were less at the end of two years under accelerated depreciation than under straight-line depreciation.

A detailed review of the printed output indicated the reasons for these results. In the first 19 weeks of simulation, the only observable growth differences between policies were a lower book net worth (NW) and market net worth (MNW) under the accelerated depreciation policy. This would logically result from a larger depreciation expense under accelerated depreciation. In the 20th week an additional unit of equipment was added to process one under straight-line depreciation; whereas, under accelerated depreciation an additional unit was not added until the 21st week. This one-week lag in acquiring an additional unit of capacity for process one resulted in the order input rate (OIR) under the accelerated depreciation policy simulation to be consistently less than under the straight-line policy simulation. Unfortunately, the one-week lag in the physical growth, because of the lower reported profit under accelerated depreciation, was never overcome by the tax-avoidance advantage of the accelerated depreciation policy during the period simulated. Therefore, the results were inconsistent with accepted financial theory.

Policy 2 results displayed the greatest effect on company growth of all revised policies employed. Under existing policy, outside funds were employed if specific conditions were met, whereas under Policy 2, no additional outside funds were permitted. Under existing policy, the final book net worth increased in relation to its initial value by a factor of 139 per cent and the final market net worth increased by a factor of 352 per cent. Under Policy 2, final book net worth decreased to 91 per cent of its initial value and final market net worth increased to 115 per cent of its initial value. The restriction to internally generated funds appeared to have greatly limited the ability of the hypothetical company to grow.

This policy comparison not only showed the extent to which restriction to internal financing limited the growth of the firm but the danger of employing too conservative a policy. Figure 28 indicates that as a result of the restriction to internal financing of growth, the cash level of the firm dropped to less than half its initial value. The company was apparently operating at a scale of operation which was rapidly decreasing its cash reserves. Had the company not recovered in the 23rd week, it might have gone out of business while pursuing its conservative financial policy.

Policy 3 represented an attempt to base the equipment replacement decision on a comparison of the next period equipment expense of continuing to employ the present equipment with the capitalized next period cost of replacing the present equipment plus its equipment expense. When the equipment expense for a machine becomes so high because of its age that the capitalized cost of a new unit of equipment plus its equipment expense is a lesser next period cost than present equipment expense, replacement normally is considered desirable.

Results for Policy 3, however, indicated that the assumed existing replacement policy was preferable in terms of overall company growth to Policy 3. This result demonstrates the value of investigating the effect of employing alternative policies in a total system environment as compared to a typical two-alternative engineering economy environment. It shows that although replacement may be desirable from the point of view of providing a least cost equipment service, the relative gain as compared to other possible uses for such funds may not be sufficient to make replacement the best use of available funds. For example, funds employed in replacement cannot be employed in increasing the absolute size of the existing process capability. Since the gain to be derived from investing in additional process capacity is of a highly complex nature, comparison of the relative desirability of employing funds for each purpose can only be evaluated as output from an integrated system model simulation. In the case of Model A, the simulation output indicated that existing policy resulted in greater company growth for the period considered than did Policy 3.

Policy 4 results indicated that the parameter value of 1.05 employed under the assumed existing policy for the labor to equipment factor in Model A was preferable in its effect upon company growth to either of the two alternative values. The values of 1.00 and 1.10 for Policies 4A and 4B resulted in substantially less final book net worth as well as market net worth. These results indicated, therefore, that an estimate of the present required labor force, as a factor in the labor acquisition decision for Model A, should be approximately 1.05 times the present equipment demand for labor. In other words, in Model A a five per cent excess of labor best offsets the training delay experienced by all newly hired factory employees.

Policy 5 results indicated that a hiring policy based on equipment demands for labor was less effective than the existing policy of basing additional hiring on a consideration of overtime demands. An interesting result was obtained when additional parameter values were employed with Policy 5 in an attempt to determine the maximizing parameter value. When parameter values of 1.05 and 1.15 were employed, no change resulted in system output. This result confirmed an initial concern in the development of Model B, of having to employ a one-month simulation interval since accounting information was not available in intervals of less than a month. The one-month simulation interval, being too long, precluded effective simulation of essentially continuous hiring policy and resulted in a series of discrete considerations of labor needs relative to equipment needs.

Policy 6 results showed that if present machine C equipment had been loaded to somewhat less than three shifts before acquiring an additional equipment unit rather than to somewhat less than two shifts, cumulative new profit at the end of the five-year period would have been increased by $56,108. This result indicated that equipment-related expenses, both direct and indirect, as a function of total equipment investment, more than overshadowed the additional required third-shift differential labor costs associated with less equipment. It may be concluded, therefore, that for the period under consideration, an improved profit position would have resulted from employing third-shift labor on existing equipment rather than acquiring an additional unit of machine C equipment.

In general, the company simulation models were effective in producing results which indicated the complex direct and indirect system effects of alternative policies. Traditional evaluation techniques, of necessity, do not consider a number of indirect effects associated with policy alternatives.

Recommendations for Further Research

The industrial dynamics simulation system provides a means of determining the long-term effect of employing a defined complex interrelationship of system variables. The system does not, in any way, define relationships between variables. Therefore, the success of an industrial dynamics simulation depends heavily on the ability of the model-builder to develop appropriate defining relationships for the variables employed. Unfortunately, surprisingly little quantitative information exists which indicates what specific factors are considered by various management personnel in making common industrial decisions and how these factors are interrelated. For example, what major factors are typically considered by management personnel in the decision to hire additional factory laborers? Empirical analysis of the factors employed in common functional decisions could provide considerable information for specification of relationships to be employed.

Information presently recorded by industrial personnel only partially meets the information needs of simulation model-builders. Therefore, it is unreasonable to expect at the present time that simulation models can be developed which give detailed consideration to specific decision areas since insufficient recorded information exists from which basic relationships can be identified. Therefore, the need exists for research into identifying the type of information that should be recorded as well as the desired interval of data collection.

Although the models developed in this study were relatively large industrial dynamics models, the range of functional coverage was sufficiently broad to preclude detailed formulation in each functional area. It is recommended, therefore, that extensive models be developed in each functional area. Information gained concerning the nature of specific functional variables would assist in defining more adequately appropriate functional relationships in broader models.

The industrial dynamics simulation system presently possesses features which limit both model-building flexibility and model capacity. The following are recommendations concerning specific industrial dynamics simulation system limitations:

1. The equation forms are presently very limited for defining non-linear relationships. Additional non-linear equation forms would increase non-linear model-building capability.

2. Additional linear equation forms also are needed to eliminate the present need to specify dummy variables as a result of equation form limitations.

3. Various round-off and absolute value equation forms also would facilitate simulation of discrete variables, such as the level of men or machines.

4. An equation form that would permit equality comparison of the value of a variable with any chosen constant would improve model construc-

tion capability. At present, only equality comparison with respect to zero is permitted.

It also is recommended that industrial dynamics model building of real-world systems be encouraged. Results of such system simulations are likely to lead to improved understanding of the sensitivity of variables of interest and of the underlying theoretical relationships between system variables.

APPENDIX A

A LISTING OF THE HYPOTHETICAL COMPANY GROWTH MODEL PROGRAM

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PAGE 1      1

     *      A100-101.DYN.RESULTS,9,9,0,0.

            COMPANY GROWTH MODEL - THREE SERIES PROCESSES


            COMPANY DEMAND

     C      MD=1500                                                  (A1)
     10A    DD.K=DD1.K+DD2.K+DD3.K+DD4.K+DD5.K+2                     (A2)
     20A    DD1.K=OB.K/AOOR.K                                        (A3)
     20A    DD2.K=MIP1.K/AP1LR.K                                     (A4)
     20A    DD3.K=MIP2.K/AP2LR.K                                     (A5)
     20A    DD4.K=MIP3.K/AP3LR.K                                     (A6)
     20A    DD5.K=FPAS.K/ASR.K                                       (A7)
     58A    FMD.K=TABHL(TFMD,DD.K,0,50,5)                            (A8)
     C      TFMD*=.2/.2/.15/.1/.075/.05/.05/.05/.05/.05/0            (A9)
     12A    CD.K=(FMD.K)(MD)                                         (A10)
     6R     OIR.KL=CD.K                                              (A11)
     1L     OB.K=OB.J+(DT)(CIR.JK-OOR.JK)                            (A12)
     6R     OOR.KL=MIR.JK                                            (A13)
     3L     AOIR.K=ACIR.J+(DT)(1/TAOIR)(OIR.JK-AOIR.J)               (A14)
     C      TAOIR=8                                                  (A15)
     3L     AOOR.K=AOOR.J+(DT)(1/TAOOR)(OCR.JK-AOOR.J)               (A16)
     C      TAOOR=6                                                  (A17)
     3L     AP1LR.K=AP1LR.J+(DT)(1/TAP1R)(MLP1R.J-AP1LR.J)           (A18)
     C      TAP1R=8                                                  (A19)
     3L     AP2LR.K=AP2LR.J+(DT)(1/TAP2R)(MLP2R.J-AP2LR.J)           (A20)
     C      TAP2R=8                                                  (A21)
     3L     AP3LR.K=AP3LR.J+(DT)(1/TAP3R)(MLP3R.J-AP3LR.J)           (A22)
     C      TAP3R=8                                                  (A23)
     3L     ASR.K=ASR.J+(DT)(1/TASR)(SR.JK-ASR.J)                    (A24)
     C      TASR=4                                                   (A25)

            MATERIAL FLOW

     13A    MISD.K=(AMU.K)(MOID)(4)                                  (A26)
     C      MOID=2                                                   (A27)
     3L     AMU.K=AMU.J+(DT)(1/MUAP)(MIR.JK-AMU.J)                   (A28)
     C      MUAP=8                                                   (A29)
     21A    MPRPA.K=(1/PAP)(MISD.K-MIS.K)                            (A30)
     C      PAP=3                                                    (A31)
     51R    MPR.KL=CLIP(MPRPA.K,0,MISD.K,MIS.K)                      (A32)
     1L     MIS.K=MIS.J+(DT)(MPR.JK-MIR.JK)                          (A33)
     12A    MIRA.K=(MIOR)(MLP1R.K)                                   (A34)
     C      MIOR=1.5                                                 (A35)
     51A    MIRD.K=CLIP(MLP1R.K,MIRA.K,MIP1.K,MMAP1)                 (A36)
     C      MMAP1=600                                                (A37)
     12A    MMOIR.K=(MOIR)(OIR.K)                                    (A38)
     C      MOIR=2                                                   (A39)
     51R    MIR.KL=CLIP(MIRD.K,OIR.K,OB.K,MMOIR.K)                   (A40)
     7A     MLP1R.K=MLP1G.JK+MLP1S.JK                                (A41)
     51R    MLP1G.KL=CLIP(MLP1F.K,MIR.K,MIP1.K,MML1G.K)              (A42)
     12A    MML1G.K=(ML1G)(MLP1G.K)                                  (A43)
     C      ML1G=2                                                   (A44)
     7A     P1RD.K=MLP1R.K-MIR.JK                                    (A45)
     51A    MLP1F.K=CLIP(MLP2R.K,MLP1A.K,MIP2.K,MMAP2)               (A46)
     C      MMAP2=550                                                (A47)
     51A    MLP1A.K=CLIP(MP1ER.K,MP1LR.K,P1L.K,CP1LA.K)              (A48)
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PAGE 2        1

13A    MP1ER.K=(P1EQL.K)(P1R.K)(P1MER.K)                         (A49)
12A    P1MER.K=(P1MLR)(P1LER)                                    (A50)
C      P1MLR=5                                                   (A51)
C      P1LER=6                                                   (A52)
13A    MP1LR.K=(P1L.K)(P1MLR)(P1R.K)                             (A53)
20A    MP1GR.K=MLP1G.JK/P1R.K                                    (A54)
18R    MLP1S.KL=(MP1GR.K)(1-P1R.K)                               (A55)
1L     MIP1.K=MIP1.J+(DT)(MIR.JK-MLP1R.J)                        (A56)
7A     MLP2R.K=MLP2G.JK+MLP2S.JK                                 (A57)
51R    MLP2G.KL=CLIP(MLP2F.K,MLP1G.K,MIP2.K,MML2G.K)             (A58)
12A    MML2G.K=(ML2G)(MLP2G.K)                                   (A59)
C      ML2G=2                                                    (A60)
51A    MLP2F.K=CLIP(MLP3R.K,MLP2A.K,MIP3.K,MMAP3)                (A61)
C      MMAP3=500                                                 (A62)
51A    MLP2A.K=CLIP(MP2ER.K,MP2LR.K,P2L.K,CP2LA.K)               (A63)
13A    MP2ER.K=(P2EQL.K)(P2R.K)(P2MER.K)                         (A64)
12A    P2MER.K=(P2MLR)(P2LER)                                    (A65)
C      P2MLR=6                                                   (A66)
C      P2LER=4                                                   (A67)
13A    MP2LR.K=(P2L.K)(P2MLR)(P2R.K)                             (A68)
20A    MP2GR.K=MLP2G.JK/P2R.K                                    (A69)
18R    MLP2S.KL=(MP2GR.K)(1-P2R.K)                               (A70)
1L     MIP2.K=MIP2.J+(DT)(MLP1G.JK-MLP2R.J)                      (A71)
7A     MLP3R.K=MLP3G.JK+MLP3S.JK                                 (A72)
51R    MLP3G.KL=CLIP(MLP3F.K,MLP2G.K,MIP3.K,MML3G.K)             (A73)
12A    MML3G.K=(ML3G)(MLP3G.K)                                   (A74)
C      ML3G=2                                                    (A75)
51A    MLP3F.K=CLIP(MP3ER.K,MP3LR.K,P3L.K,CP3LA.K)               (A76)
13A    MP3ER.K=(P3EQL.K)(P3R.K)(P3MER.K)                         (A77)
12A    P3MER.K=(P3MLR)(P3LER)                                    (A78)
C      P3MLR=90                                                  (A79)
C      P3LER=.3                                                  (A80)
13A    MP3LR.K=(P3L.K)(P3MLR)(P3R.K)                             (A81)
20A    MP3GR.K=MLP3G.JK/P3R.K                                    (A82)
18R    MLP3S.KL=(MP3GR.K)(1-P3R.K)                               (A83)
1L     MIP3.K=MIP3.J+(DT)(MLP2G.JK-MLP3R.J)                      (A84)
1L     FPAS.K=FPAS.J+(DT)(MLP3G.JK-SR.JK)                        (A85)
20R    SR.KL=FPAS.K/SD                                           (A86)
C      SD=1                                                      (A87)

       PROCESS ACQUISITICN SELECTION

51A    RR12.K=CLIP(1,0,FMLP2.K,FMLP1.K)                          (A88)
51A    RR13.K=CLIP(5,0,MLP3G.K,FMLP1.K)                          (A89)
13A    FMLP1.K=(MLP1G.JK)(P2R.K)(P3R.K)                          (A90)
12A    FMLP2.K=(MLP2G.JK)(P3R.K)                                 (A91)
51A    RR23.K=CLIP(3,0,MLP3G.K,FMLP2.K)                          (A92)
8A     PSI.K=RR12.K+RR23.K+RR13.K                                (A93)
59A    PS.K=TABLE(TPS,PSI.K,0,9,1)                               (A94)
C      TPS*=3/3/0/2/0/0/1/0/2/1                                  (A95)
18A    AIRFU.K=(AOIR.K)(1-UA)                                    (A96)
C      UA=.05                                                    (A97)
51A    PAD.K=CLIP(PS.K,0,AIRFU.K,M123.K)                         (A98)
54A    M12.K=MIN(MLP1R.K,IMRP2.K)                                (A99)
54A    M123.K=MIN(M12.K,IMRP3.K)                                 (A100)
42A    IMRP2.K=MLP2G.K/((P1R.K)(P2R.K))                          (A101)
46A    IMRP3.K=(MLP3G.K)(1)(1)/((P1R.K)(P2R.K)(P3R.K))           (A102)
51A    MC1.K=CLIP(1,0,FAI.K,MCP1R)                               (A103)
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PAGE 3      1

C      MCP1R=22000                                          (A104)
7A     PAD1.K=PAD.K-1                                       (A105)
49A    P1I.K=SWITCH(2,0,PAD1.K)                             (A106)
8A     P1A.K=MC1.K+P1I.K-3                                  (A107)
49R    P1EAQ.KL=SWITCH(1,0,P1A.K)                           (A108)
49A    CP1EA.K=SWITCH(MCP1R,0,P1A.K)                        (A109)
51A    MC2.K=CLIP(1,0,FAI.K,MCP2R)                          (A110)
C      MCP2R=30000                                          (A111)
7A     PAD2.K=PAD.K-2                                       (A112)
49A    P2I.K=SWITCH(4,0,PAD2.K)                             (A113)
8A     P2A.K=MC2.K+P2I.K-5                                  (A114)
49R    P2EAQ.KL=SWITCH(1,0,P2A.K)                           (A115)
49A    CP2EA.K=SWITCH(MCP2R,0,P2A.K)                        (A116)
51A    MC3.K=CLIP(1,0,FAI.K,MCP3R)                          (A117)
C      MCP3R=15000                                          (A118)
7A     PAD3.K=PAD.K-3                                       (A119)
49A    P3I.K=SWITCH(6,0,PAD3.K)                             (A120)
8A     P3A.K=MC3.K+P3I.K-7                                  (A121)
49R    P3EAQ.KL=SWITCH(1,0,P3A.K)                           (A122)
49A    CP3EA.K=SWITCH(MCP3R,0,P3A.K)                        (A123)

       FACTORY LABOR APPORTIONMENT

51A    LP.K=CLIP(5,0,EFL.K,TLR.K)                           (A124)
8A     TLR.K=CP1LA.K+CP2LA.K+CP3LA.K                        (A125)
7A     LPI.K=LP.K+PS.K                                      (A126)
7A     LIP1.K=LPI.K-1                                       (A127)
7A     LIP2.K=LPI.K-2                                       (A128)
7A     LIP3.K=LPI.K-3                                       (A129)
49A    CP1L.K=SWITCH(CP1LA.K,0,LIP1.K)                      (A130)
12A    CP1LA.K=(P1EQL.K)(P1LER)                             (A131)
49A    CP2L.K=SWITCH(CP2LA.K,0,LIP2.K)                      (A132)
12A    CP2LA.K=(P2EQL.K)(P2LER)                             (A133)
49A    CP3L.K=SWITCH(CP3LA.K,0,LIP3.K)                      (A134)
12A    CP3LA.K=(P3EQL.K)(P3LER)                             (A135)
51A    LPP1.K=CLIP(CP1LA.K,0,LPI.K,5)                       (A136)
51A    LPP2.K=CLIP(CP2LA.K,0,LPI.K,5)                       (A137)
51A    LPP3.K=CLIP(CP3LA.K,0,LPI.K,5)                       (A138)
7A     LR23.K=EFL.K-CP1L.K                                  (A139)
7A     LR13.K=EFL.K-CP2L.K                                  (A140)
7A     LR12.K=EFL.K-CP3L.K                                  (A141)
50A    LLP12.K=(CP1LA.K)(LR13.K)/(CP1LA.K+CP3LA.K)          (A142)
50A    LLP13.K=(CP1LA.K)(LR12.K)/(CP1LA.K+CP2LA.K)          (A143)
50A    LLP21.K=(CP2LA.K)(LR23.K)/(CP2LA.K+CP3LA.K)          (A144)
50A    LLP23.K=(CP2LA.K)(LR12.K)/(CP1LA.K+CP2LA.K)          (A145)
50A    LLP31.K=(CP3LA.K)(LR23.K)/(CP2LA.K+CP3LA.K)          (A146)
50A    LLP32.K=(CP3LA.K)(LR13.K)/(CP1LA.K+CP3LA.K)          (A147)
9A     P1L.K=CP1L.K+LPP1.K+SLP12.K+SLP13.K                  (A148)
49A    SLP12.K=SWITCH(LLP12.K,0,LIP2.K)                     (A149)
49A    SLP13.K=SWITCH(LLP13.K,0,LIP3.K)                     (A150)
9A     P2L.K=CP2L.K+LPP2.K+SLP21.K+SLP23.K                  (A151)
49A    SLP21.K=SWITCH(LLP21.K,0,LIP1.K)                     (A152)
49A    SLP23.K=SWITCH(LLP23.K,0,LIP3.K)                     (A153)
9A     P3L.K=CP3L.K+LPP3.K+SLP31.K+SLP32.K                  (A154)
49A    SLP31.K=SWITCH(LLP31.K,0,LIP1.K)                     (A155)
49A    SLP32.K=SWITCH(LLP32.K,0,LIP2.K)                     (A156)

       PROCESS 1 EQUIPMENT ACQUIRED
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PAGE 4       1

1L     P1EQL.K=P1EQL.J+(DT)(P1EAO.JK-P1ERQ.JK)                (A157)
51R    P1M1S.KL=CLIP(1.0,P1EQL.K,P1EL1.K)                     (A158)
7A     P1EL1.K=IP1EL+1                                        (A159)
C      IP1EL=2                                                (A160)
1L     TP1M1.K=TP1M1.J+(DT)(P1M1S.JK+T11J.J)                  (A161)
58A    EP1M1.K=TABHL(TEP11,TP1M1.K,0,260,26)                  (A162)
C      TEP11*=60/50/45/52/75/105/140/187/240/290/0            (A163)
51A    P1M1E.K=CLIP(EP1M1.K,0,TP1M1.K,1)                      (A164)
51R    P1M2S.KL=CLIP(1.0,P1EQL.K,P1EL2.K)                     (A165)
7A     P1EL2.K=IP1EL+2                                        (A166)
1L     TP1M2.K=TP1M2.J+(DT)(P1M2S.JK+T12J.J)                  (A167)
58A    EP1M2.K=TABHL(TEP11,TP1M2.K,0,260,26)                  (A168)
51A    P1M2E.K=CLIP(EP1M2.K,0,TP1M2.K,1)                      (A169)
51R    P1M3S.KL=CLIP(1.0,P1EQL.K,P1EL3.K)                     (A170)
7A     P1EL3.K=IP1EL+3                                        (A171)
1L     TP1M3.K=TP1M3.J+(DT)(P1M3S.JK+T13J.J)                  (A172)
58A    EP1M3.K=TABHL(TEP11,TP1M3.K,0,260,26)                  (A173)
51A    P1M3E.K=CLIP(EP1M3.K,0,TP1M3.K,1)                      (A174)
51R    P1M4S.KL=CLIP(1.0,P1EQL.K,P1EL4.K)                     (A175)
7A     P1EL4.K=IP1EL+4                                        (A176)
1L     TP1M4.K=TP1M4.J+(DT)(P1M4S.JK+T14J.J)                  (A177)
58A    EP1M4.K=TABHL(TEP11,TP1M4.K,0,260,26)                  (A178)
51A    P1M4E.K=CLIP(EP1M4.K,0,TP1M4.K,1)                      (A179)
51R    P1M5S.KL=CLIP(1.0,P1EQL.K,P1EL5.K)                     (A180)
7A     P1EL5.K=IP1EL+5                                        (A181)
1L     TP1M5.K=TP1M5.J+(DT)(P1M5S.JK+T15J.J)                  (A182)
58A    EP1M5.K=TABHL(TEP11,TP1M5.K,0,260,26)                  (A183)
51A    P1M5E.K=CLIP(EP1M5.K,0,TP1M5.K,1)                      (A184)
58A    RP1M1.K=TABHL(TRP11,TP1M1.K,0,260,26)                  (A185)
C      TRP11*=.5/.8/.9/.95/.95/.95/.95/.9/.85/.60/0           (A186)
51A    P1M1R.K=CLIP(RP1M1.K,0,TP1M1.K,1)                      (A187)
58A    RP1M2.K=TABHL(TRP11,TP1M2.K,0,260,26)                  (A188)
51A    P1M2R.K=CLIP(RP1M2.K,0,TP1M2.K,1)                      (A189)
58A    RP1M3.K=TABHL(TRP11,TP1M3.K,0,260,26)                  (A190)
51A    P1M3R.K=CLIP(RP1M3.K,0,TP1M3.K,1)                      (A191)
58A    RP1M4.K=TABHL(TRP11,TP1M4.K,0,260,26)                  (A192)
51A    P1M4R.K=CLIP(RP1M4.K,0,TP1M4.K,1)                      (A193)
58A    RP1M5.K=TABHL(TRP11,TP1M5.K,0,260,26)                  (A194)
51A    P1M5R.K=CLIP(RP1M5.K,0,TP1M5.K,1)                      (A195)
10A    SRCN1.K=P1M1R.K+P1M2R.K+P1M3R.K+P1M4R.K+P1M5R.K+0      (A196)
49A    RI11.K=SWITCH(0,1,P1M1R.K)                             (A197)
49A    RI12.K=SWITCH(0,1,P1M2R.K)                             (A198)
49A    RI13.K=SWITCH(0,1,P1M3R.K)                             (A199)
49A    RI14.K=SWITCH(0,1,P1M4R.K)                             (A200)
49A    RI15.K=SWITCH(0,1,P1M5R.K)                             (A201)
10A    SRIN1.K=RI11.K+RI12.K+RI13.K+RI14.K+RI15.K+0           (A202)
20A    P1R.K=SRCP1.K/SRIP1.K                                  (A203)
1L     TD1M1.K=TD1M1.J+(DT)(P1M1S.JK+T11J.J)                  (A204)
58A    DP1M1.K=TABHL(TDP11,TD1M1.K,0,234,26)                  (A205)
C      TDP11*=100/100/100/100/100/100/100/100/100/0           (A206)
51A    D11FA.K=CLIP(DP1M1.K,0,TD1M1.K,1)                      (A207)
51A    D11FB.K=CLIP(DP1M1.K,0,TD1M1.K,SS11)                   (A208)
7A     P1M1D.K=D11FA.K-D11FB.K                                (A209)
7A     TD11.K=TD1M1.K-SS11                                    (A210)
C      SS11=209                                               (A211)
49A    CFS11.K=SWITCH(SV11,0,TD11.K)                          (A212)
C      SV11=1200                                              (A213)
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PAGE 5     1

1L    TDIM2.K=TDIM2.J+(DT)(PIM2S.JK+T12J.J)                 (A214)
58A   DPIM2.K=TABHL(TDPI1,TDIM2.K,0,234,26)                 (A215)
51A   DI2FA.K=CLIP(DPIM2.K,0,TDIM2.K,1)                     (A216)
51A   DI2FB.K=CLIP(DPIM2.K,0,TDIM2.K,SS12)                  (A217)
7A    PIM2D.K=DI2FA.K-DI2FB.K                               (A218)
7A    TD12.K=TDIM2.K-SS12                                   (A219)
C     SS12=209                                              (A220)
49A   CFS12.K=SWITCH(SV12,0,TD12.K)                         (A221)
C     SV12=1200                                             (A222)
1L    TDIM3.K=TDIM3.J+(DT)(PIM3S.JK+T13J.J)                 (A223)
58A   DPIM3.K=TABHL(TDPI1,TDIM3.K,0,234,26)                 (A224)
51A   DI3FA.K=CLIP(DPIM3.K,0,TDIM3.K,1)                     (A225)
51A   DI3FB.K=CLIP(DPIM3.K,0,TDIM3.K,SS13)                  (A226)
7A    PIM3D.K=DI3FA.K-DI3FB.K                               (A227)
7A    TD13.K=TDIM3.K-SS13                                   (A228)
C     SS13=209                                              (A229)
49A   CFS13.K=SWITCH(SV13,0,TD13.K)                         (A230)
C     SV13=1200                                             (A231)
1L    TDIM4.K=TDIM4.J+(DT)(PIM4S.JK+T14J.J)                 (A232)
58A   DPIM4.K=TABHL(TDPI1,TDIM4.K,0,234,26)                 (A233)
51A   DI4FA.K=CLIP(DPIM4.K,0,TDIM4.K,1)                     (A234)
51A   DI4FB.K=CLIP(DPIM4.K,0,TDIM4.K,SS14)                  (A235)
7A    PIM4D.K=DI4FA.K-DI4FB.K                               (A236)
7A    TD14.K=TDIM4.K-SS14                                   (A237)
C     SS14=209                                              (A238)
49A   CFS14.K=SWITCH(SV14,0,TD14.K)                         (A239)
C     SV14=1200                                             (A240)
1L    TDIM5.K=TDIM5.J+(DT)(PIM5S.JK+T15J.J)                 (A250)
58A   DPIM5.K=TABHL(TDPI1,TDIM5.K,0,234,26)                 (A251)
51A   DI5FA.K=CLIP(DPIM5.K,0,TDIM5.K,1)                     (A252)
51A   DI5FB.K=CLIP(DPIM5.K,0,TDIM5.K,SS15)                  (A253)
7A    PIM5D.K=DI5FA.K-DI5FB.K                               (A254)
7A    TD15.K=TDIM5.K-SS15                                   (A255)
C     SS15=209                                              (A256)
49A   CFS15.K=SWITCH(SV15,0,TD15.K)                         (A257)
C     SV15=1200                                             (A258)
10A   CFSP1.K=CFS11.K+CFS12.K+CFS13.K+CFS14.K+CFS15.K+0     (A259)
49A   P11RO.K=SWITCH(1,0,RI11L.K)                           (A260)
52L   RI11L.K=RI11L.J+(DT)(1-RI1I.J+P11RO.J+0)              (A261)
7A    RS11.K=MRS11.K+DRC11.K                                (A262)
51A   DRC11.K=CLIP(0,1,TPIM1.K,HRT11)                       (A263)
C     AR11=.85                                              (A264)
C     HRT11=104                                             (A265)
49A   T11J.K=SWITCH(MMLP1,0,RS11.K)                         (A266)
C     MMLP1=260                                             (A267)
51A   RI1I.K=CLIP(1,0,RS11.K,1)                             (A268)
6N    RI11L=-1                                              (A269)
49A   P12RO.K=SWITCH(1,0,RI12L.K)                           (A270)
52L   RI12L.K=RI12L.J+(DT)(1-RI2I.J+P12RO.J+0)              (A271)
7A    RS12.K=MRS12.K+DRC12.K                                (A272)
51A   DRC12.K=CLIP(0,1,TPIM2.K,HRT12)                       (A273)
C     AR12=.85                                              (A274)
C     HRT12=104                                             (A275)
49A   T12J.K=SWITCH(MMLP1,0,RS12.K)                         (A276)
51A   RI2I.K=CLIP(1,0,RS12.K,1)                             (A277)
6N    RI12L=-1                                              (A278)
49A   P13RO.K=SWITCH(1,0,RI13L.K)                           (A279)
52L   RI13L.K=RI13L.J+(DT)(1-RI3I.J+P13RO.J+0)              (A280)
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PAGE 6      1

   7A    RS13.K=MRS13.K+DRC13.K                                      (A281)
   51A   DRC13.K=CLIP(0,1,TP1M3.K,HRT13)                             (A282)
   C     AR13=.85                                                    (A283)
   C     HRT13=104                                                   (A284)
   49A   T13J.K=SWITCH(MMLP1,0,RS13.K)                               (A285)
   51A   R13I.K=CLIP(1,0,RS13.K,1)                                   (A286)
   6N    RI13L=-1                                                    (A287)
   49A   P14RQ.K=SWITCH(1,0,RI14L.K)                                 (A288)
   52L   RI14L.K=RI14L.J+(DT)(1-R14I.J+P14RQ.J+0)                    (A289)
   7A    RS14.K=MRS14.K+DRC14.K                                      (A290)
   51A   DRC14.K=CLIP(0,1,TP1M4.K,HRT14)                             (A291)
   C     AR14=.85                                                    (A292)
   C     HRT14=104                                                   (A293)
   49A   T14J.K=SWITCH(MMLP1,0,RS14.K)                               (A294)
   51A   R14I.K=CLIP(1,0,RS14.K,1)                                   (A295)
   6N    RI14L=-1                                                    (A296)
   49A   P15RQ.K=SWITCH(1,0,RI15L.K)                                 (A297)
   52L   RI15L.K=RI15L.J+(DT)(1-R15I.J+P15RQ.J+0)                    (A298)
   7A    RS15.K=MRS15.K+DRC15.K                                      (A299)
   51A   DRC15.K=CLIP(0,1,TP1M5.K,HRT15)                             (A300)
   C     AR15=.85                                                    (A301)
   C     HRT15=104                                                   (A302)
   49A   T15J.K=SWITCH(MMLP1,0,RS15.K)                               (A303)
   51A   R15I.K=CLIP(1,0,RS15.K,1)                                   (A304)
   6N    RI15L=-1                                                    (A305)
   10A   P1RQ.K=P11RQ.K+P12RQ.K+P13RQ.K+P14RQ.K+P15RQ.K+0            (A306)

         PROCESS 2 EQUIPMENT ACQUIRED

   1L    P2EQL.K=P2EQL.J+(DT)(P2EAQ.JK-P2ERQ.JK)                     (A307)
   51R   P2M1S.KL=CLIP(1,0,P2EQL.K,P2EL1.K)                          (A308)
   7A    P2EL1.K=IP2EL+1                                             (A309)
   C     IP2EL=3                                                     (A310)
   1L    TP2M1.K=TP2M1.J+(DT)(P2M1S.JK+T21J.J)                       (A311)
   58A   EP2M1.K=TABHL(TEP21,TP2M1.K,0,260,26)                       (A312)
   C     TEP21*=45/37/32/37/48/67/100/140/180/225/0                  (A313)
   51A   P2M1E.K=CLIP(EP2M1.K,0,TP2M1.K,1)                           (A314)
   51R   P2M2S.KL=CLIP(1,0,P2EQL.K,P2EL2.K)                          (A315)
   7A    P2EL2.K=IP2EL+2                                             (A316)
   1L    TP2M2.K=TP2M2.J+(DT)(P2M2S.JK+T22J.J)                       (A317)
   58A   EP2M2.K=TABHL(TEP21,TP2M2.K,0,260,26)                       (A318)
   51A   P2M2E.K=CLIP(EP2M2.K,0,TP2M2.K,1)                           (A319)
   51R   P2M3S.KL=CLIP(1,0,P2EQL.K,P2EL3.K)                          (A320)
   7A    P2EL3.K=IP2EL+3                                             (A321)
   1L    TP2M3.K=TP2M3.J+(DT)(P2M3S.JK+T23J.J)                       (A322)
   58A   EP2M3.K=TABHL(TEP21,TP2M3.K,0,260,26)                       (A323)
   51A   P2M3E.K=CLIP(EP2M3.K,0,TP2M3.K,1)                           (A324)
   51R   P2M4S.KL=CLIP(1,0,P2EQL.K,P2EL4.K)                          (A325)
   7A    P2EL4.K=IP2EL+4                                             (A326)
   1L    TP2M4.K=TP2M4.J+(DT)(P2M4S.JK+T24J.J)                       (A327)
   58A   EP2M4.K=TABHL(TEP21,TP2M4.K,0,260,26)                       (A328)
   51A   P2M4E.K=CLIP(EP2M4.K,0,TP2M4.K,1)                           (A329)
   51R   P2M5S.KL=CLIP(1,0,P2EQL.K,P2EL5.K)                          (A330)
   7A    P2EL5.K=IP2EL+5                                             (A331)
   1L    TP2M5.K=TP2M5.J+(DT)(P2M5S.JK+T25J.J)                       (A332)
   58A   EP2M5.K=TABHL(TEP21,TP2M5.K,0,260,26)                       (A333)
   51A   P2M5E.K=CLIP(EP2M5.K,0,TP2M5.K,1)                           (A334)
   58A   RP2M1.K=TABHL(TRP21,TP2M1.K,0,234,26)                       (A335)
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PAGE 7      1

C      TRP21*=.9/.95/.98/.98/.98/.98/.98/.95/.90/0                (A336)
51A    P2M1R.K=CLIP(RP2M1.K,0,TP2M1.K,1)                          (A337)
58A    RP2M2.K=TABHL(TRP21,TP2M2.K,0,234,26)                      (A338)
51A    P2M2R.K=CLIP(RP2M2.K,0,TP2M2.K,1)                          (A339)
58A    RP2M3.K=TABHL(TRP21,TP2M3.K,0,234,26)                      (A340)
51A    P2M3R.K=CLIP(RP2M3.K,0,TP2M3.K,1)                          (A341)
58A    RP2M4.K=TABHL(TRP21,TP2M4.K,0,234,26)                      (A342)
51A    P2M4R.K=CLIP(RP2M4.K,0,TP2M4.K,1)                          (A343)
58A    RP2M5.K=TABHL(TRP21,TP2M5.K,0,234,26)                      (A344)
51A    P2M5R.K=CLIP(RP2M5.K,0,TP2M5.K,1)                          (A345)
10A    SRCN2.K=P2M1R.K+P2M2R.K+P2M3R.K+P2M4R.K+P2M5R.K+0          (A346)
49A    RI21.K=SWITCH(0,1,P2M1R.K)                                 (A347)
49A    RI22.K=SWITCH(0,1,P2M2R.K)                                 (A348)
49A    RI23.K=SWITCH(0,1,P2M3R.K)                                 (A349)
49A    RI24.K=SWITCH(0,1,P2M4R.K)                                 (A350)
49A    RI25.K=SWITCH(0,1,P2M5R.K)                                 (A351)
10A    SRIN2.K=RI21.K+RI22.K+RI23.K+RI24.K+RI25.K+0               (A352)
20A    P2R.K=SRCP2.K/SRIP2.K                                      (A353)
1L     TD2M1.K=TD2M1.J+(DT)(P2M1S.JK+T21J.J)                      (A354)
58A    DP2M1.K=TABHL(TDP21,TD2M1.K,0,234,26)                      (A355)
C      TDP21*=120/120/120/120/120/120/120/120/0                   (A356)
51A    D21FA.K=CLIP(DP2M1.K,0,TD2M1.K,1)                          (A357)
51A    D21FB.K=CLIP(DP2M1.K,0,TD2M1.K,SS21)                       (A358)
7A     P2M1D.K=D21FA.K-D21FB.K                                    (A359)
7A     TD21.K=TD2M1.K-SS21                                        (A360)
C      SS21=209                                                   (A361)
49A    CFS21.K=SWITCH(SV21,0,TD21.K)                              (A362)
C      SV21=5040                                                  (A363)
1L     TD2M2.K=TD2M2.J+(DT)(P2M2S.JK+T22J.J)                      (A364)
58A    DP2M2.K=TABHL(TDP21,TD2M2.K,0,234,26)                      (A365)
51A    D22FA.K=CLIP(DP2M2.K,0,TD2M2.K,1)                          (A366)
51A    D22FB.K=CLIP(DP2M2.K,0,TD2M2.K,SS22)                       (A367)
7A     P2M2D.K=D22FA.K-D22FB.K                                    (A368)
7A     TD22.K=TD2M2.K-SS22                                        (A369)
C      SS22=209                                                   (A370)
49A    CFS22.K=SWITCH(SV22,0,TD22.K)                              (A371)
C      SV22=5040                                                  (A372)
1L     TD2M3.K=TD2M3.J+(DT)(P2M3S.JK+T23J.J)                      (A373)
58A    DP2M3.K=TABHL(TDP21,TD2M3.K,0,234,26)                      (A374)
51A    D23FA.K=CLIP(DP2M3.K,0,TD2M3.K,1)                          (A375)
51A    D23FB.K=CLIP(DP2M3.K,0,TD2M3.K,SS23)                       (A376)
7A     P2M3D.K=D23FA.K-D23FB.K                                    (A377)
7A     TD23.K=TD2M3.K-SS23                                        (A378)
C      SS23=209                                                   (A379)
49A    CFS23.K=SWITCH(SV23,0,TD23.K)                              (A380)
C      SV23=5040                                                  (A381)
1L     TD2M4.K=TD2M4.J+(DT)(P2M4S.JK+T24J.J)                      (A382)
58A    DP2M4.K=TABHL(TDP21,TD2M4.K,0,234,26)                      (A383)
51A    D24FA.K=CLIP(DP2M4.K,0,TD2M4.K,1)                          (A384)
51A    D24FB.K=CLIP(DP2M4.K,0,TD2M4.K,SS24)                       (A385)
7A     P2M4D.K=D24FA.K-D24FB.K                                    (A386)
7A     TD24.K=TD2M4.K-SS24                                        (A387)
C      SS24=209                                                   (A388)
49A    CFS24.K=SWITCH(SV24,0,TD24.K)                              (A389)
C      SV24=5040                                                  (A390)
1L     TD2M5.K=TD2M5.J+(DT)(P2M5S.JK+T25J.J)                      (A391)
58A    DP2M5.K=TABHL(TDP21,TD2M5.K,0,234,26)                      (A392)
51A    D25FA.K=CLIP(DP2M5.K,0,TD2M5.K,1)                          (A393)
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PAGE 8       1

     51A     D25FB.K=CLIP(DP2M5.K,0,TD2M5.K,SS25)                          (A394)
     7A      P2M5D.K=D25FA.K-D25FB.K                                       (A395)
     7A      TD25.K=TD2M5.K-SS25                                           (A396)
     C       SS25=209                                                      (A397)
     49A     CFS25.K=SWITCH(SV25,0,TD25.K)                                 (A398)
     C       SV25=5040                                                     (A399)
     10A     CFSP2.K=CFS21.K+CFS22.K+CFS23.K+CFS24.K+CFS25.K+0             (A400)
     49A     P21RQ.K=SWITCH(1,0,RI21L.K)                                   (A401)
     52L     RI21L.K=RI21L.J+(DT)(1-R21I.J+P21RQ.J+0)                      (A402)
     7A      RS21.K=MRS21.K+DRC21.K                                        (A403)
     51A     DRC21.K=CLIP(0,1,TP2M1.K,HRT21)                               (A404)
     C       AR21=.90                                                      (A405)
     C       HRT21=104                                                     (A406)
     49A     T21J.K=SWITCH(MMLP2,0,RS21.K)                                 (A407)
     C       MMLP2=234                                                     (A408)
     51A     R21I.K=CLIP(1,0,RS21.K,1)                                     (A409)
     6N      RI21L=-1                                                      (A410)
     49A     P22RQ.K=SWITCH(1,0,RI22L.K)                                   (A411)
     52L     RI22L.K=RI22L.J+(DT)(1-R22I.J+P22RQ.J+0)                      (A412)
     7A      RS22.K=MRS22.K+DRC22.K                                        (A413)
     51A     DRC22.K=CLIP(0,1,TP2M2.K,HRT22)                               (A414)
     C       AR22=.90                                                      (A415)
     C       HRT22=104                                                     (A416)
     49A     T22J.K=SWITCH(MMLP2,0,RS22.K)                                 (A417)
     51A     R22I.K=CLIP(1,0,RS22.K,1)                                     (A418)
     6N      RI22L=-1                                                      (A419)
     49A     P23RQ.K=SWITCH(1,0,RI23L.K)                                   (A420)
     52L     RI23L.K=RI23L.J+(DT)(1-R23I.J+P23RQ.J+0)                      (A421)
     7A      RS23.K=MRS23.K+DRC23.K                                        (A422)
     51A     DRC23.K=CLIP(0,1,TP2M3.K,HRT22)                               (A423)
     C       AR23=.90                                                      (A424)
     C       HRT23=104                                                     (A425)
     49A     T23J.K=SWITCH(MMLP2,0,RS23.K)                                 (A426)
     51A     R23I.K=CLIP(1,0,RS23.K,1)                                     (A427)
     6N      RI23L=-1                                                      (A428)
     49A     P24RQ.K=SWITCH(1,0,RI24L.K)                                   (A429)
     52L     RI24L.K=RI24L.J+(DT)(1-R24I.J+P24RQ.J+0)                      (A430)
     7A      RS24.K=MRS24.K+DRC24.K                                        (A431)
     51A     DRC24.K=CLIP(0,1,TP2M4.K,HRT24)                               (A432)
     C       AR24=.90                                                      (A433)
     C       HRT24=104                                                     (A434)
     49A     T24J.K=SWITCH(MMLP2,0,RS24.K)                                 (A435)
     51A     R24I.K=CLIP(1,0,RS24.K,1)                                     (A436)
     6N      RI24L=-1                                                      (A437)
     49A     P25RQ.K=SWITCH(1,0,RI25L.K)                                   (A438)
     52L     RI25L.K=RI25L.J+(DT)(1-R25I.J+P25RQ.J+0)                      (A439)
     7A      RS25.K=MRS25.K+DRC25.K                                        (A440)
     51A     DRC25.K=CLIP(0,1,TP2M5.K,HRT25)                               (A441)
     C       AR25=.90                                                      (A442)
     C       HRT25=104                                                     (A443)
     49A     T25J.K=SWITCH(MMLP2,0,RS25.K)                                 (A444)
     51A     R25I.K=CLIP(1,0,RS25.K,1)                                     (A445)
     6N      RI25L=-1                                                      (A446)
     10A     P2RQ.K=P21RQ.K+P22RQ.K+P23RQ.K+P24RQ.K+P25RQ.K+0              (A447)

             PROCESS 3 EQUIPMENT ACQUIRED

     1L      P3EQL.K=P3EQL.J+(DT)(P3EAQ.JK-P3ERQ.JK)                       (A448)
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51R   P3M1S.KL=CLIP(1,0,P3EQL.K,P3EL1.K)                        (A449)
7A    P3EL1.K=IP3EL+1                                           (A450)
C     IP3EL=2                                                   (A451)
1L    TP3M1.K=TP3M1.J+(DT)(P3M1S.JK+T31J.J)                     (A452)
58A   EP3M1.K=TABHL(TEP31,TP3M1.K,0,312,26)                     (A453)
C     TEP31*=38/31/25/25/28/37/60/90/135/180/225/270/0          (A454)
51A   P3M1E.K=CLIP(EP3M1.K,0,TP3M1.K,1)                         (A455)
51R   P3M2S.KL=CLIP(1,0,P3EQL.K,P3EL2.K)                        (A456)
7A    P3EL2.K=IP3EL+2                                           (A457)
1L    TP3M2.K=TP3M2.J+(DT)(P3M2S.JK+T32J.J)                     (A458)
58A   EP3M2.K=TABHL(TEP31,TP3M2.K,0,312,26)                     (A459)
51A   P3M2E.K=CLIP(EP3M2.K,0,TP3M2.K,1)                         (A460)
51R   P3M3S.KL=CLIP(1,0,P3EQL.K,P3EL3.K)                        (A461)
7A    P3EL3.K=IP3EL+3                                           (A462)
1L    TP3M3.K=TP3M3.J+(DT)(P3M3S.JK+T33J.J)                     (A463)
58A   EP3M3.K=TABHL(TEP31,TP3M3.K,0,312,26)                     (A464)
51A   P3M3E.K=CLIP(EP3M3.K,0,TP3M3.K,1)                         (A465)
51R   P3M4S.KL=CLIP(1,0,P3EQL.K,P3EL4.K)                        (A466)
7A    P3EL4.K=IP3EL+4                                           (A467)
1L    TP3M4.K=TP3M4.J+(DT)(P3M4S.JK+T34J.J)                     (A468)
58A   EP3M4.K=TABHL(TEP31,TP3M4.K,0,312,26)                     (A469)
51A   P3M4E.K=CLIP(EP3M4.K,0,TP3M4.K,1)                         (A470)
51R   P3M5S.KL=CLIP(1,0,P3EQL.K,P3EL5.K)                        (A471)
7A    P3EL5.K=IP3EL+5                                           (A472)
1L    TP3M5.K=TP3M5.J+(DT)(P3M5S.JK+T35J.J)                     (A473)
58A   EP3M5.K=TABHL(TEP31,TP3M5.K,0,312,26)                     (A474)
51A   P3M5E.K=CLIP(EP3M5.K,0,TP3M5.K,1)                         (A475)
58A   RP3M1.K=TABHL(TRP31,TP3M1.K,0,338,26)                     (A476)
C     TRP31*=.95/.97/.98/.98/.98/.98/.98/.95/.92/.88/.65/.50/.30/0   (A477)
51A   P3M1R.K=CLIP(RP3M1.K,0,TP3M1.K,1)                         (A478)
58A   RP3M2.K=TABHL(TRP31,TP3M2.K,0,338,26)                     (A479)
51A   P3M2R.K=CLIP(RP3M2.K,0,TP3M2.K,1)                         (A480)
58A   RP3M3.K=TABHL(TRP31,TP3M3.K,0,338,26)                     (A481)
51A   P3M3R.K=CLIP(RP3M3.K,0,TP3M3.K,1)                         (A482)
58A   RP3M4.K=TABHL(TRP31,TP3M4.K,0,338,26)                     (A483)
51A   P3M4R.K=CLIP(RP3M4.K,0,TP3M4.K,1)                         (A484)
58A   RP3M5.K=TABHL(TRP31,TP3M5.K,0,338,26)                     (A485)
51A   P3M5R.K=CLIP(RP3M5.K,0,TP3M5.K,1)                         (A486)
10A   SRCN3.K=P3M1R.K+P3M2R.K+P3M3R.K+P3M4R.K+P3M5R.K+0         (A487)
49A   RI31.K=SWITCH(0,1,P3M1R.K)                                (A488)
49A   RI32.K=SWITCH(0,1,P3M2R.K)                                (A489)
49A   RI33.K=SWITCH(0,1,P3M3R.K)                                (A490)
49A   RI34.K=SWITCH(0,1,P3M4R.K)                                (A491)
49A   RI35.K=SWITCH(0,1,P3M5R.K)                                (A492)
10A   SRIN3.K=RI31.K+RI32.K+RI33.K+RI34.K+RI35.K+0              (A493)
20A   P3R.K=SRCP3.K/SRIP3.K                                     (A494)
1L    TD3M1.K=TD3M1.J+(DT)(P3M1S.JK+T31J.J)                     (A495)
58A   DP3M1.K=TABHL(TDP31,TD3M1.K,0,234,26)                     (A496)
C     TDP31*=60/60/60/60/60/60/60/60/60/0                       (A497)
51A   D31FA.K=CLIP(DP3M1.K,0,TD3M1.K,1)                         (A498)
51A   D31FB.K=CLIP(DP3M1.K,0,TD3M1.K,SS31)                      (A499)
7A    P3M1D.K=D31FA.K-D31FB.K                                   (A500)
7A    TD31.K=TD3M1.K-SS31                                       (A501)
C     SS31=209                                                  (A502)
49A   CFS31.K=SWITCH(SV31,0,TD31.K)                             (A503)
C     SV31=2520                                                 (A504)
1L    TD3M2.K=TD3M2.J+(DT)(P3M2S.JK+T32J.J)                     (A505)
58A   DP3M2.K=TABHL(TDP31,TD3M2.K,0,234,26)                     (A506)
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PAGE 10      1

51A    D32FA.K=CLIP(DP3M2.K,0,TD3M2.K,1)                     (A507)
51A    D32FB.K=CLIP(DP3M2.K,0,TD3M2.K,SS32)                  (A508)
7A     P3M2D.K=D32FA.K-D32FB.K                               (A509)
7A     TD32.K=TD3M2.K-SS32                                   (A510)
C      SS32=209                                              (A511)
49A    CFS32.K=SWITCH(SV32,0,TD32.K)                         (A512)
C      SV32=2520                                             (A513)
1L     TD3M3.K=TD3M3.J+(DT)(P3M3S.JK+T33J.J)                 (A514)
58A    CP3M3.K=TABHL(TDP31,TD3M3.K,0,234,26)                 (A515)
51A    D33FA.K=CLIP(DP3M3.K,0,TD3M3.K,1)                     (A516)
51A    D33FB.K=CLIP(DP3M3.K,0,TD3M3.K,SS33)                  (A517)
7A     P3M3D.K=D33FA.K-D33FB.K                               (A518)
7A     TD33.K=TD3M3.K-SS33                                   (A519)
C      SS33=209                                              (A520)
49A    CFS33.K=SWITCH(SV33,0,TD33.K)                         (A521)
C      SV33=2520                                             (A522)
49A    CFS34.K=SWITCH(SV34,0,TD34.K)                         (A523)
C      SV34=2520                                             (A524)
1L     TD3M4.K=TD3M4.J+(DT)(P3M4S.JK+T34J.J)                 (A525)
58A    DP3M4.K=TABHL(TDP31,TD3M4.K,0,234,26)                 (A526)
51A    D34FA.K=CLIP(DP3M4.K,0,TD3M4.K,1)                     (A527)
51A    D34FB.K=CLIP(DP3M4.K,0,TD3M4.K,SS34)                  (A528)
7A     P3M4D.K=D34FA.K-D34FB.K                               (A529)
7A     TD34.K=TD3M4.K-SS34                                   (A530)
C      SS34=209                                              (A531)
1L     TD3M5.K=TD3M5.J+(DT)(P3M5S.JK+T35J.J)                 (A532)
58A    DP3M5.K=TABHL(TDP31,TD3M5.K,0,234,26)                 (A533)
51A    D35FA.K=CLIP(DP3M5.K,0,TD3M5.K,1)                     (A534)
51A    D35FB.K=CLIP(DP3M5.K,0,TD3M5.K,SS35)                  (A535)
7A     P3M5D.K=C35FA.K-D35FB.K                               (A536)
7A     TD35.K=TD3M5.K-SS35                                   (A537)
C      SS35=209                                              (A538)
49A    CFS35.K=SWITCH(SV35,0,TD35.K)                         (A539)
C      SV35=2520                                             (A540)
10A    CFSP3.K=CFS31.K+CFS32.K+CFS33.K+CFS34.K+CFS35.K+0     (A541)
49A    P31RQ.K=SWITCH(1,0,RI31L.K)                           (A542)
52L    RI31L.K=RI31L.J+(DT)(1-R31I.J+P31RQ.J+0)              (A543)
7A     RS31.K=MRS31.K+DRC31.K                                (A544)
51A    DRC31.K=CLIP(0,1,TP3M1.K,HRT31)                       (A545)
C      AR31=.85                                              (A546)
C      HRT31=104                                             (A547)
49A    T31J.K=SWITCH(MMLP3,0,RS31.K)                         (A548)
C      MMLP3=338                                             (A549)
51A    R31I.K=CLIP(1,0,RS31.K,1)                             (A550)
6N     RI31L=-1                                              (A551)
49A    P32RQ.K=SWITCH(1,0,RI32L.K)                           (A552)
52L    RI32L.K=RI32L.J+(DT)(1-R32I.J+P32RQ.J+0)              (A553)
7A     RS32.K=MRS32.K+DRC32.K                                (A554)
51A    DRC32.K=CLIP(0,1,TP3M2.K,HRT32)                       (A555)
C      AR32=.85                                              (A556)
C      HRT32=104                                             (A557)
49A    T32J.K=SWITCH(MMLP3,0,R32.K)                          (A558)
51A    R32I.K=CLIP(1,0,RS32.K,1)                             (A559)
6N     R132L=-1                                              (A560)
49A    P33RQ.K=SWITCH(1,0,RI33L.K)                           (A561)
52L    RI33L.K=RI33L.J+(CT)(1-R33I.J+P33RQ.J+0)              (A562)
7A     RS33.K=MRS33.K+DRC33.K                                (A563)
51A    DRC33.K=CLIP(0,1,TP3M3.K,HRT33)                       (A564)
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PAGE 11     1

     C      AR33=.85                                              (A565)
     C      HRT33=104                                             (A566)
     49A    T33J.K=SWITCH(MMLP3.0,RS33.K)                         (A567)
     51A    R33I.K=CLIP(1,0,RS33.K,1)                             (A568)
     6N     RI33L=-1                                              (A569)
     49A    P34RQ.K=SWITCH(1,0,RI34L.K)                           (A570)
     52L    RI34L.K=RI34L.J+(DT)(1-R34I.J+P34RQ.J+0)              (A571)
     7A     RS34.K=MRS34.K+DRC34.K                                (A572)
     51A    DRC34.K=CLIP(0,1,TP3M4.K,HRT34)                       (A573)
     C      AR34=.85                                              (A574)
     C      HRT34=104                                             (A575)
     49A    T34J.K=SWITCH(MMLP3.0,RS34.K)                         (A576)
     51A    R34I.K=CLIP(1,0,RS34.K,1)                             (A577)
     6N     RI34L=-1                                              (A578)
     49A    P35RQ.K=SWITCH(1,0,RI35L.K)                           (A579)
     52L    RI35L.K=RI35L.J+(DT)(1-R35I.J+P35RQ.J+0)              (A580)
     7A     RS35.K=MRS35.K+DRC35.K                                (A581)
     51A    DRC35.K=CLIP(0,1,TP3M5.K,HRT35)                       (A582)
     C      AR35=.85                                              (A583)
     C      HRT35=104                                             (A584)
     49A    T35J.K=SWITCH(MMLP3.0,RS35.K)                         (A585)
     51A    R35I.K=CLIP(1,0,RS35.K,1)                             (A586)
     6N     RI35L=-1                                              (A587)
     10A    P3RQ.K=P31RQ.K+P32RQ.K+P33RQ.K+P34RQ.K+P35RQ.K+0      (A588)

            PROCESS 1 INITIAL EQUIPMENT

     1L     TP11.K=TP11.J+(DT)(1+TI11J.J)                         (A589)
     58A    E11.K=TABHL(TEP11,TP11.K,0,260,26)                    (A590)
     51A    P11E.K=CLIP(E11.K,0,IP1EL,1)                          (A591)
     58A    R11.K=TABHL(TRP11,TP11.K,0,260,26)                    (A592)
     51A    P11R.K=CLIP(R11.K,0,IP1EL,1)                          (A593)
     49A    RI111.K=SWITCH(0,1,P11R.K)                            (A594)
     1L     TP12.K=TP12.J+(DT)(1+TI12J.J)                         (A595)
     58A    E12.K=TABHL(TEP11,TP12.K,0,260,26)                    (A596)
     51A    P12E.K=CLIP(E12.K,0,IP1EL,2)                          (A597)
     58A    R12.K=TABHL(TRP11,TP12.K,0,260,26)                    (A598)
     51A    P12R.K=CLIP(R12.K,0,IP1EL,2)                          (A599)
     49A    RI112.K=SWITCH(0,1,P12R.K)                            (A600)
     1L     TP13.K=TP13.J+(DT)(1+TI13J.J)                         (A601)
     58A    E13.K=TABHL(TEP11,TP13.K,0,260,26)                    (A602)
     51A    P13E.K=CLIP(E13.K,0,IP1EL,3)                          (A603)
     58A    R13.K=TABHL(TRP11,TP13.K,0,260,26)                    (A604)
     51A    P13R.K=CLIP(R13.K,0,IP1EL,3)                          (A605)
     49A    RI113.K=SWITCH(0,1,P13R.K)                            (A606)
     1L     TP14.K=TP14.J+(DT)(1+TI14J.J)                         (A607)
     58A    E14.K=TABHL(TEP11,TP14.K,0,260,26)                    (A608)
     51A    P14E.K=CLIP(E14.K,0,IP1EL,4)                          (A609)
     58A    R14.K=TABHL(TRP11,TP14.K,0,260,26)                    (A610)
     51A    P14R.K=CLIP(R14.K,0,IP1EL,4)                          (A611)
     49A    RI114.K=SWITCH(0,1,P14R.K)                            (A612)
     1L     TP15.K=TP15.J+(DT)(1+TI15J.J)                         (A613)
     58A    E15.K=TABHL(TEP11,TP15.K,0,260,26)                    (A614)
     51A    P15E.K=CLIP(E15.K,0,IP1EL,5)                          (A615)
     58A    R15.K=TABHL(TRP11,TP15.K,0,260,26)                    (A616)
     51A    P15R.K=CLIP(R15.K,0,IP1EL,5)                          (A617)
     49A    RI115.K=SWITCH(0,1,P15R.K)                            (A618)
     1L     DT11.K=DT11.J+(DT)(1+TI11J.J)                         (A619)
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PAGE 12 1

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58A   D11.K=TABHL(TDP11,DT11.K,0,234,26)                          (A620)
51A   D11E.K=CLIP(D11.K,0,DT11.K,S11)                             (A621)
C     S11=209                                                     (A622)
7A    P11D.K=D11.K-D11E.K                                         (A623)
1L    DT12.K=DT12.J+(DT)(1+TI12J.J)                               (A624)
58A   D12.K=TABHL(TDP11,DT12.K,0,234,26)                          (A625)
51A   D12E.K=CLIP(D12.K,0,DT12.K,S12)                             (A626)
C     S12=209                                                     (A627)
7A    P12D.K=D12.K-D12E.K                                         (A628)
1L    DT13.K=DT13.J+(DT)(1+TI13J.J)                               (A629)
58A   D13.K=TABHL(TDP11,DT13.K,0,234,26)                          (A630)
51A   D13E.K=CLIP(D13.K,0,DT13.K,S13)                             (A631)
C     S13=209                                                     (A632)
7A    P13D.K=D13.K-D13E.K                                         (A633)
1L    DT14.K=DT14.J+(DT)(1+TI14J.J)                               (A634)
58A   D14.K=TABHL(TDP11,DT14.K,0,234,26)                          (A635)
51A   D14E.K=CLIP(D14.K,0,DT14.K,S14)                             (A636)
7A    P14D.K=D14.K-D14E.K                                         (A637)
C     S14=209                                                     (A638)
1L    DT15.K=DT15.J+(DT)(1+TI15J.J)                               (A639)
58A   D15.K=TABHL(TDP11,DT15.K,0,234,26)                          (A640)
51A   D15E.K=CLIP(D15.K,0,DT15.K,S15)                             (A641)
7A    P15D.K=D15.K-D15E.K                                         (A642)
7A    ST11.K=DT11.K-S11                                           (A643)
49A   CSP11.K=SWITCH(SVP11,0,ST11.K)                              (A644)
C     SVP11=1200                                                  (A645)
7A    ST12.K=DT12.K-S12                                           (A646)
49A   CSP12.K=SWITCH(SVP12,0,ST12.K)                              (A647)
C     SVP12=1200                                                  (A648)
7A    ST13.K=DT13.K-S13                                           (A649)
49A   CSP13.K=SWITCH(SVP13,0,ST13.K)                              (A650)
C     SVP13=1200                                                  (A651)
7A    ST14.K=DT14.K-S14                                           (A652)
49A   CSP14.K=SWITCH(SVP14,0,ST14.K)                              (A653)
C     SVP14=1200                                                  (A654)
7A    ST15.K=DT15.K-S15                                           (A655)
49A   CSP15.K=SWITCH(SVP15,0,ST15.K)                              (A656)
C     SVP15=1200                                                  (A657)
10A   CSP1T.K=CFSP1.K+CSP11.K+CSP12.K+CSP13.K+CSP14.K+CSP15.K     (A658)
49A   RQ11.K=SWITCH(1,0,RIL11.K)                                  (A659)
52L   RIL11.K=RIL11.J+(DT)(1-RI11I.J+RQ11.J+0)                    (A660)
7A    RSI11.K=MR115.K+DR11C.K                                     (A661)
51A   DR11C.K=CLIP(0,1,TP11.K,HRI11)                              (A662)
C     ARI11=.85                                                   (A663)
C     HRI11=104                                                   (A664)
49A   TI11J.K=SWITCH(MMLP1,0,RSI11.K)                             (A665)
51A   RI11I.K=CLIP(1,0,RSI11.K,1)                                 (A666)
6N    RIL11=-1                                                    (A667)
49A   RQ12.K=SWITCH(1,0,RIL12.K)                                  (A668)
52L   RIL12.K=RIL12.J+(DT)(1-RI12I.J+RQ12.J+0)                    (A669)
7A    RSI12.K=MR125.K+DR12C.K                                     (A670)
51A   DR12C.K=CLIP(0,1,TP12.K,HRI12)                              (A671)
C     ARI12=.85                                                   (A672)
C     HRI12=104                                                   (A673)
49A   TI12J.K=SWITCH(MMLP1,0,RSI12.K)                             (A674)
51A   RI12I.K=CLIP(1,0,RSI12.K,1)                                 (A675)
6N    RIL12=-1                                                    (A676)
49A   RQ13.K=SWITCH(1,0,RIL13.K)                                  (A677)
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PAGE 13     1

52L   RIL13.K=RIL13.J+(DT)(1-RI13I.J+RQ13.J+0)                    (A678)
7A    RSI13.K=MR13S.K+DR13C.K                                     (A679)
51A   DR13C.K=CLIP(0.1,TP13.K,HRI13)                              (A680)
C     ARI13=.85                                                   (A681)
C     HRI13=104                                                   (A682)
49A   TI13J.K=SWITCH(MMLP1.0.RSI13.K)                             (A683)
51A   RI13I.K=CLIP(1.0.RSI13.K.1)                                 (A684)
6N    RIL13=-1                                                    (A685)
49A   RQ14.K=SWITCH(1.0.RIL14.K)                                  (A686)
52L   RIL14.K=RIL14.J+(DT)(1-RI14I.J+RQ14.J+0)                    (A687)
7A    RSI14.K=MR14S.K+DR14C.K                                     (A688)
51A   DR14C.K=CLIP(0.1,TP14.K.HRI14)                              (A689)
C     ARI14=.85                                                   (A690)
C     HRI14=104                                                   (A691)
49A   TI14J.K=SWITCH(MMLP1.0.RSI14.K)                             (A692)
51A   RI14I.K=CLIP(1.0,RSI14.K.1)                                 (A693)
6N    RIL14=-1                                                    (A694)
49A   RQ15.K=SWITCH(1.0.RIL15.K)                                  (A695)
52L   RIL15.K=RIL15.J+(DT)(1-RI15I.J+RQ15.J+0)                    (A696)
7A    RSI15.K=MR15S.K+DR15C.K                                     (A697)
51A   DR15C.K=CLIP(0.1.TP15.K.HRI15)                              (A698)
C     ARI15=.85                                                   (A699)
C     HRI15=104                                                   (A700)
49A   TI15J.K=SWITCH(MMLP1.0.RSI15.K)                             (A701)
51A   RI15I.K=CLIP(1,0,RSI15.K.1)                                 (A702)
6N    RIL15=-1                                                    (A703)
10A   P1IRQ.K=RQ11.K+RQ12.K+RQ13.K+RQ14.K+RQ15.K+0                (A704)
7R    P1ERQ.KL=P1IRQ.K+P1RQ.K                                     (A705)
7A    P1EE.K=P1IEE.K+P1AEE.K                                      (A706)
10A   P1IEE.K=P11E.K+P12E.K+P13E.K+P14E.K+P15E.K+0                (A707)
10A   P1AEE.K=P1M1E.K+P1M2E.K+P1M3E.K+P1M4E.K+P1M5E.K+0           (A708)
1L    P1RFD.K=P1RFD.J+(DT)(P1ED.J+0)                              (A709)
10A   P1AED.K=P1M1D.K+P1M2D.K+P1M3D.K+P1M4D.K+P1M5D.K+0           (A710)
10A   P1IED.K=P11D.K+P12D.K+P13D.K+P14D.K+P15D.K+0                (A711)

      PROCESS 2 INITIAL EQUIPMENT

1L    TP21.K=TP21.J+(DT)(1+TI21J.J)                               (A712)
58A   E21.K=TABHL(TEP21,TP21.K,0,260,26)                          (A713)
51A   P21E.K=CLIP(E21.K,0.IP2EL,1)                                (A714)
58A   R21.K=TABHL(TRP21,TP21.K,0,234,26)                          (A715)
51A   P21R.K=CLIP(R21.K,0.IP2EL,1)                                (A716)
49A   RII21.K=SWITCH(0.1,P21R.K)                                  (A717)
1L    TP22.K=TP22.J+(DT)(1+TI22J.J)                               (A718)
58A   E22.K=TABHL(TEP21,TP22.K,0,260,26)                          (A719)
51A   P22E.K=CLIP(E22.K,0,IP2EL,2)                                (A720)
58A   R22.K=TABHL(TRP21,TP22.K,0,234,26)                          (A721)
51A   P22R.K=CLIP(R22.K,0,IP2EL,2)                                (A722)
49A   RII22.K=SWITCH(0,1.P22R.K)                                  (A723)
1L    TP23.K=TP23.J+(DT)(1+TI23J.J)                               (A724)
58A   E23.K=TABHL(TEP21,TP23.K,0,260,26)                          (A725)
51A   P23E.K=CLIP(E23.K,0,IP2EL,3)                                (A726)
58A   R23.K=TABHL(TRP21,TP23.K,0,234,26)                          (A727)
51A   P23R.K=CLIP(R23.K,0.IP2EL,3)                                (A728)
49A   RII23.K=SWITCH(0,1.P23R.K)                                  (A729)
10A   SRCI1.K=P11R.K+P12R.K+P13R.K+P14R.K+P15R.K+0                (A730)
7A    SRCP1.K=SRCN1.K+SRCI1.K                                     (A731)
10A   SRII1.K=RII11.K+RII12.K+RII13.K+RII14.K+RII15.K+0           (A732)
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PAGE 14      1

8A    SRCI2.K=P21R.K+P22R.K+P23R.K                        (A733)
7A    SRCP2.K=SRCN2.K+SRCI2.K                             (A734)
8A    SRII2.K=RII21.K+RII22.K+RII23.K                     (A735)
7A    SRCI3.K=P31R.K+P32R.K                               (A736)
7A    SRCP3.K=SRCN3.K+SRCI3.K                             (A737)
7A    SRII3.K=RII31.K+RII32.K                             (A738)
7A    SRIP1.K=SRIN1.K+SRII1.K                             (A739)
7A    SRIP2.K=SRIN2.K+SRII2.K                             (A740)
7A    SRIP3.K=SRIN3.K+SRII3.K                             (A741)
1L    DT21.K=DT21.J+(DT)(1+TI21J.J)                       (A742)
58A   D21.K=TABHL(TDP21.DT21.K.0.234.26)                  (A743)
51A   D21E.K=CLIP(D21.K.0.DT21.K.S21)                     (A744)
7A    P21D.K=D21.K-D21E.K                                 (A745)
C     S21=209                                             (A746)
1L    DT22.K=DT22.J+(DT)(1+TI22J.J)                       (A747)
58A   D22.K=TABHL(TDP21.DT22.K.0.234.26)                  (A748)
51A   D22E.K=CLIP(D22.K.0.DT22.K.S22)                     (A749)
7A    P22D.K=D22.K-D22E.K                                 (A750)
C     S22=209                                             (A751)
1L    DT23.K=DT23.J+(DT)(1+TI23J.J)                       (A752)
58A   D23.K=TABHL(TDP21.DT23.K.0.234.26)                  (A753)
51A   D23E.K=CLIP(D23.K.0.DT23.K.S23)                     (A754)
7A    P23D.K=D23.K-D23E.K                                 (A755)
C     S23=209                                             (A756)
7A    ST21.K=DT21.K-S21                                   (A757)
49A   CSP21.K=SWITCH(SVP21.0.ST21.K)                      (A758)
C     SVP21=5040                                          (A759)
7A    ST22.K=DT22.K-S22                                   (A760)
49A   CSP22.K=SWITCH(SVP22.0.ST22.K)                      (A761)
C     SVP22=5040                                          (A762)
7A    ST23.K=DT23.K-S23                                   (A763)
49A   CSP23.K=SWITCH(SVP23.0.ST23.K)                      (A764)
C     SVP23=5040                                          (A765)
9A    CSP2T.K=CFSP2.K+CSP21.K+CSP22.K+CSP23.K             (A766)
49A   RQ21.K=SWITCH(1.0.RIL21.K)                          (A767)
52L   RIL21.K=RIL21.J+(DT)(1-RI21I.J+RQ21.J+0)            (A768)
7A    RSI21.K=MR21S.K+DR21C.K                             (A769)
51A   DR21C.K=CLIP(0.1.TP21.K.HRI21)                      (A770)
C     ARI21=.90                                           (A771)
C     HRI21=104                                           (A772)
49A   TI21J.K=SWITCH(MMLF2.0.RSI21.K)                     (A773)
51A   RI21I.K=CLIP(1.0.RSI21.K.1)                         (A774)
6N    RIL21=-1                                            (A775)
49A   RQ22.K=SWITCH(1.0.RIL22.K)                          (A776)
52L   RIL22.K=RIL22.J+(DT)(1-RI22I.J+RQ22.J+0)            (A777)
7A    RSI22.K=MR22S.K+DR22C.K                             (A778)
51A   DR22C.K=CLIP(0.1.TP22.K.HRI22)                      (A779)
C     ARI22=.90                                           (A780)
C     HRI22=104                                           (A781)
49A   TI22J.K=SWITCH(MMLF2.0.RSI22.K)                     (A782)
51A   RI22I.K=CLIP(1.0.RSI22.K.1)                         (A783)
6N    RIL22=-1                                            (A784)
49A   RQ23.K=SWITCH(1.0.RIL23.K)                          (A785)
52L   RIL23.K=RIL23.J+(DT)(1-RI23I.J+RQ23.J+0)            (A786)
7A    RSI23.K=MR23S.K+DR23C.K                             (A787)
51A   DR23C.K=CLIP(0.1.TP23.K.HRI23)                      (A788)
C     ARI23=.90                                           (A789)
C     HRI23=104                                           (A790)
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PAGE 15      1

     49A   TI23J.K=SWITCH(MMLP2.0,RSI23.K)                              (A791)
     51A   RI231.K=CLIP(1,0,RSI23.K,1)                                  (A792)
     6N    RIL23=-1                                                     (A793)
     8A    P2IRQ.K=RQ21.K+RQ22.K+RQ23.K                                 (A794)
     7R    P2ERQ.KL=P2IRQ.K+P2RQ.K                                      (A795)
     7A    P2EE.K=P2IEE.K+P2AEE.K                                       (A796)
     8A    P2IEE.K=P21E.K+P22E.K+P23E.K                                 (A797)
     10A   P2AEE.K=P2M1E.K+P2M2E.K+P2M3E.K+P2M4E.K+P2M5E.K+0            (A798)
     1L    P2RFD.K=P2RFD.J+(DT)(P2ED.J+0)                               (A799)
     10A   P2AED.K=P2M1D.K+P2M2D.K+P2M3D.K+P2M4D.K+P2M5D.K+0            (A800)
     8A    P2IED.K=P21D.K+P22D.K+P23D.K                                 (A801)

           PROCESS 3 INITIAL ECUIPMENT

     1L    TP31.K=TP31.J+(DT)(1+TI31J.J)                                (A802)
     58A   E31.K=TABHL(TEP31,TP31.K,0,312,26)                           (A803)
     51A   P31E.K=CLIP(E31.K,0,IP3EL,1)                                 (A804)
     58A   R31.K=TABHL(TRP31,TP31.K,0,338,26)                           (A805)
     51A   P31R.K=CLIP(R31.K,0,IP3EL,1)                                 (A806)
     49A   RII31.K=SWITCH(0,1,P31R.K)                                   (A807)
     1L    TP32.K=TP32.J+(DT)(1+TI32J.J)                                (A808)
     58A   E32.K=TABHL(TEP31,TP32.K,0,312,26)                           (A809)
     51A   P32E.K=CLIP(E32.K,0,IP3EL,2)                                 (A810)
     58A   R32.K=TABHL(TRP31,TP32.K,0,338,26)                           (A811)
     51A   P32R.K=CLIP(R32.K,0,IP3EL,2)                                 (A812)
     49A   RII32.K=SWITCH(0,1,P32R.K)                                   (A813)
     C     S16=209                                                      (A814)
     1L    DT31.K=DT31.J+(DT)(1+TI31J.J)                                (A815)
     58A   D31.K=TABHL(TDP31,DT31.K,0,234,26)                           (A816)
     51A   D31E.K=CLIP(D31.K,0,DT31.K,S31)                              (A817)
     7A    P31D.K=D31.K-D31E.K                                          (A818)
     C     S31=209                                                      (A819)
     1L    DT32.K=DT32.J+(DT)(1+TI32J.J)                                (A820)
     58A   D32.K=TABHL(TDP31,DT32.K,0,234,26)                           (A821)
     51A   D32E.K=CLIP(D32.K,0,DT32.K,S32)                              (A822)
     7A    P32D.K=D32.K-D32E.K                                          (A823)
     C     S32=209                                                      (A824)
     7A    ST31.K=DT31.K-S31                                            (A825)
     49A   CSP31.K=SWITCH(SVP31,0,ST31.K)                               (A826)
     C     SVP31=2520                                                   (A827)
     7A    ST32.K=DT32.K-S32                                            (A828)
     49A   CSP32.K=SWITCH(SVP32,0,ST32.K)                               (A829)
     C     SVP32=2520                                                   (A830)
     8A    CSP3T.K=CFSP3.K+CSP31.K+CSP32.K                              (A831)
     49A   RO31.K=SWITCH(1,0,RIL31.K)                                   (A832)
     52L   RIL31.K=RIL31.J+(DT)(1-RI311.J+RO31.J+0)                     (A833)
     7A    RSI31.K=MR31S.K+DR31C.K                                      (A834)
     51A   DR31C.K=CLIP(0,1,TP31.K,HRI31)                               (A835)
     C     ARI31=.85                                                    (A836)
     C     HRI31=104                                                    (A837)
     49A   TI31J.K=SWITCH(MMLP3,0,RSI31.K)                              (A838)
     51A   RI311.K=CLIP(1,0,RSI31.K,1)                                  (A839)
     6N    RIL31=-1                                                     (A840)
     49A   RO32.K=SWITCH(1,0,RIL32.K)                                   (A841)
     52L   RIL32.K=RIL32.J+(DT)(1-RI321.J+RO32.J+0)                     (A842)
     7A    RSI32.K=MR32S.K+DR32C.K                                      (A843)
     51A   DR32C.K=CLIP(0,1,TP32.K,HRI32)                               (A844)
     C     ARI32=.85                                                    (A845)
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PAGE 18      1

C      HRI32=104                                                   (A846)
49A    TI32J.K=SWITCH(MMLP3,0,RSI32.K)                             (A847)
51A    RI32I.K=CLIP(1,0,RSI32.K,1)                                 (A848)
6N     RIL32=-1                                                    (A849)
7A     P3IRQ.K=RQ31.K+RQ32.K                                       (A850)
7R     P3ERQ.KL=P3IRQ.K+P3RQ.K                                     (A851)
7A     P3EE.K=P3IEE.K+P3AEE.K                                      (A852)
7A     P3IEE.K=P31E.K+P32E.K                                       (A853)
10A    P3AEE.K=P3M1E.K+P3M2E.K+P3M3E.K+P3M4E.K+P3M5E.K+0           (A854)
1L     P3RFD.K=P3RFD.J+(DT)(P3ED.J+0)                              (A855)
10A    P3AED.K=P3M1D.K+P3M2D.K+P3M3D.K+P3M4D.K+P3M5D.K+0           (A856)
7A     P3IED.K=P31D.K+P32D.K                                       (A857)

       FACTORY LABOR

16A    FLRFE.K=(P1EQL.K)(P1LER)+(P2EQL.K)(P2LER)+(P3EQL.K)(P3LER)+(1)(0)   (A858)
12A    FLD.K=(LTEF)(FLRFE.K)                                       (A859)
51R    FLHR.KL=CLIP(0,FHRWU.K,FLQ.K,FLD.K)                         (A860)
7A     FLQ.K=FLIT.K+TFL.K                                          (A861)
21A    FHRWU.K=(1/FLAT)(FLD.K-FLQ.K)                               (A862)
C      FLAT=2                                                      (A863)
20R    FLTR.KL=FLIT.K/FTD                                          (A864)
C      FTD=2                                                       (A865)
1L     FLIT.K=FLIT.J+(DT)(FLHR.JK-FLTR.JK)                         (A866)
12R    FLLR.KL=(FTP)(FLQ.K)                                        (A867)
C      FTP=.08                                                     (A868)
1L     TFL.K=TFL.J+(DT)(FLTR.JK-FLLR.JK)                           (A869)
15A    EFL.K=(1)(TFL.K)+(PEUFL)(FLIT.K)                            (A870)
C      PEUFL=.5                                                    (A871)

       PROFESSIONAL LABOR

12A    PLD.K=(PFLRD)(FLQ.K)                                        (A872)
C      PFLRD=.1                                                    (A873)
51R    PLHR.KL=CLIP(0,PHRWU.K,PLQ.K,PLD.K)                         (A874)
7A     PLQ.K=PLIT.K+TPL.K                                          (A875)
21A    PHRWU.K=(1/PLAT)(PLD.K-PLQ.K)                               (A876)
C      PLAT=6                                                      (A877)
20R    PLTR.KL=PLIT.K/PLDY                                         (A878)
C      PLDY=26                                                     (A879)
1L     PLIT.K=PLIT.J+(DT)(PLHR.JK-PLTR.JK)                         (A880)
12R    PLLR.KL=(PTP)(PLQ.K)                                        (A881)
C      PTP=.05                                                     (A882)
1L     TPL.K=TPL.J+(DT)(PLTR.JK-PLLR.JK)                           (A883)

       COSTS

1L     CASH.K=CASH.J+(DT)(CASHT.JK-0)                              (A884)
10R    CASHT.KL=CASHA.K+CASHB.K-CP1EA.K-CP2EA.K-CP3EA.K+0          (A885)
11A    CASHA.K=ARPR.K-DPPR.K-IER.K-GAER.K-TRU.K-OCR.K+CSP1T.K+CSP2T.K   (A886)
10A    CASHB.K=-MCR.K-PLCR.K-FLCR.K+CSP3T.K+DCIR.K+0               (A887)
27A    ARPR.K=(AR.K/CPD)-BDER.K                                    (A888)
C      CPD=4                                                       (A889)
44A    IER.K=(IR.K)(FDL.K)/52                                      (A890)
15A    GAER.K=(GAEF)(FLQ.K)+(GAOF)(AOOR.K)                         (A891)
C      GAEF=2                                                      (A892)
C      GAOF=.5                                                     (A893)
51A    TRU.K=CLIP(TR.K,0,GP.K,0)                                   (A894)
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PAGE 17      1

51A    TR.K=CLIP(TRB.K,TRA.K,GP.K,25000)                                   (A895)
12A    TRA.K=(ATR)(GPR.K)                                                  (A896)
C      ATR=.30                                                             (A897)
22A    TRB.K=(1/52)((ATR)(25000)+(BTR)(AGP.K))                             (A898)
C      BTR=.50                                                             (A899)
7A     OCR.K=OCRA.K+OCRD.K                                                 (A900)
10A    OCRA.K=OFF+OCRL.K+P1EE.K+P2EE.K+P3EE.K+0                            (A901)
C      OFF=1400                                                            (A902)
12A    OCRL.K=(EOF)(FLQ.K)                                                 (A903)
C      EOF=12                                                              (A904)
9A     OCRD.K=P1ED.K+P2ED.K+P3ED.K+BDR.K                                   (A905)
6A     MCR.K=APPR.K                                                        (A906)
12A    PLCR.K=(APWR)(PLQ.K)                                                (A907)
C      APWR=150                                                            (A908)
12A    FLCR.K=(AFWR)(FLQ.K)                                                (A909)
C      AFWR=80                                                             (A910)

       FINANCIAL

20A    DER.K=FDL.K/MNW.K                                                   (A911)
58A    IR.K=TABHL(TIR,DER.K,0,0.7,0.1)                                     (A912)
C      TIR*=0.06/0.065/0.07/0.08/0.095/0.12/0.15/0.25                      (A913)
20A    MNW.K=YNPAT.K/ERCSR.JK                                              (A914)
12A    YNPAT.K=(ANPAT.K)(52)                                               (A915)
3L     ANPAT.K=ANPAT.J+(DT)(1/TAAPT)(NPAT.J-ANPAT.J)                       (A916)
C      TAAPT=12                                                            (A917)
7R     ERCSR.KL=EPRFI+FDLA.K                                               (A918)
C      EPRFI=0.45                                                          (A919)
18A    FDLA.K=(DER.K)(EPRFI-IR.K)                                          (A920)
51A    DII.K=CLIP(1,0,IR.K,IRCO)                                           (A921)
C      IRCO=0.08                                                           (A922)
51A    MNPID.K=CLIP(0,1,ANPR.K,MNPRD)                                      (A923)
C      MNPRD=0.20                                                          (A924)
7A     DCAI.K=DII.K+MNPID.K                                                (A925)
49A    DFA.K=SWITCH(DFI,0,DCAI.K)                                          (A926)
C      DFI=20000                                                           (A927)
7A     FAI.K=CASH.K-MCB                                                    (A928)
C      MCB=20000                                                           (A929)
20A    DPPR.K=FDL.K/NDP.K                                                  (A930)
12A    NDP.K=(YODP)(52)                                                    (A931)
C      YODP=5                                                              (A932)
1L     FDL.K=FDL.J+(DT)(DCIR.J-DPPR.J)                                     (A933)
7A     NPAT.K=GPR.K-TRU.K                                                  (A934)
1L     PTD.K=PTD.J+(DT)(NPAT.J-0)                                          (A935)
3L     ANPR.K=ANPR.J+(DT)(1/TANPR)(NPATR.J-ANPR.J)                         (A936)
C      TANPR=6                                                             (A937)
44A    NPATR.K=(NPAT.K)(52)/MNW.K                                          (A938)
12A    GP.K=(52)(GPR.K)                                                    (A939)
11A    GPR.K=SIR.K-IER.K-GAER.K-OCR.K-MCR.K-PLCR.K-FLCR.K-BDER.K           (A940)
12A    SIR.K=(OIR.JK)(PP)                                                  (A941)
C      PP=225                                                              (A942)
7A     AGP.K=GP.K-25000                                                    (A943)
7A     TA.K=CA.K+FA.K                                                      (A944)
9A     CA.K=CASH.K+TI.K+AR.K-RFBD.K                                        (A945)
12A    RFBD.K=(BDP)(AR.K)                                                  (A946)
12A    BDER.K=(BDP)(ARIR.JK)                                               (A947)
C      BDP=.05                                                             (A948)
9A     FA.K=NEBV.K+BCV-RFBDP.K+LAND                                        (A949)
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PAGE 18     1

 6A    CL.K=AP.K                                                      (A950)
 6A    FL.K=FDL.K                                                     (A951)
 7A    TL.K=CL.K+FL.K                                                 (A952)
 7A    NW.K=TA.K-TL.K                                                 (A953)

       ASSET AND LIABILITY LEVELS

10A    TI.K=MISI.K+MIP1I.K+MIP2I.K+MIP3I.K+FPASI.K+0                  (A954)
12A    MISI.K=(MIS.K)(MPP)                                            (A955)
12A    MIP1I.K=(MIP1.K)(MV1.K)                                        (A956)
12A    MIP2I.K=(MIP2.K)(MV2.K)                                        (A957)
12A    MIP3I.K=(MIP3.K)(MV3.K)                                        (A958)
12A    FPASI.K=(FPAS.K)(PP)                                           (A959)
20A    P1MLF.K=1/P1MLR                                                (A960)
20A    P2MLF.K=1/P2MLR                                                (A961)
20A    P3MLF.K=1/P3MLR                                                (A962)
 8A    SPMLF.K=P1MLF.K+P2MLF.K+P3MLF.K                                (A963)
 7A    DMFP.K=PF-MPP                                                  (A964)
46A    MV1.K=(P1MLF.K)(.5)(DMFP.K)/((SPMLF.K)(1)(1))                  (A965)
14A    P12MF.K=P1MLF.K+(.5)(P2MLF.K)                                  (A966)
44A    MV2.K=(P12MF.K)(DMFP.K)/SPMLF.K                                (A967)
16A    P23MF.K=(1)(P1MLF.K)+(1)(P2MLF.K)+(.5)(P3MLF.K)+(1)(0)         (A968)
44A    MV3.K=(P23MF.K)(DMFP.K)/SPMLF.K                                (A969)
 8A    NEBV.K=P1EBV.K+P2EBV.K+P3EBV.K                                 (A970)
 7A    P1EBV.K=P1ECV.K-P1RFD.K                                        (A971)
12A    P1ECV.K=(P1IEC)(P1ECQ.K)                                       (A972)
 1L    P1ECQ.K=P1ECQ.J+(DT)(P1EAQ.JK+0)                               (A973)
 C     P1IEC=22000                                                    (A974)
 7A    P2EBV.K=P2ECV.K-P2RFD.K                                        (A975)
12A    P2ECV.K=(P2IEC)(P2ECQ.K)                                       (A976)
 1L    P2ECQ.K=P2ECQ.J+(DT)(P2EAQ.JK+0)                               (A977)
 C     P2IEC=30000                                                    (A978)
 7A    P3EBV.K=P3ECV.K-P3RFD.K                                        (A979)
12A    P3ECV.K=(P3IEC)(P3ECQ.K)                                       (A980)
 1L    P3ECQ.K=P3ECQ.J+(DT)(P3EAQ.JK+0)                               (A981)
 C     P3IEC=15000                                                    (A982)
 C     P1MD=100                                                       (A983)
 C     P2MD=120                                                       (A984)
 C     P3MD=60                                                        (A985)
42A    BDR.K=BCV/((YBD)(52))                                          (A986)
 C     BCV=208000                                                     (A987)
 C     YBD=40                                                         (A988)
 1L    RFBDP.K=RFBDP.J+(DT)(BDR.J+0)                                  (A989)
 C     LAND=8000                                                      (A990)
 1L    AP.K=AP.J+(DT)(APIR.JK-APPR.J)                                 (A991)
20A    APPR.K=AP.K/APD                                                (A992)
 C     APD=1                                                          (A993)
12R    APIR.KL=(MPR.JK)(MPP)                                          (A994)
 C     MPP=10                                                         (A995)
52L    AR.K=AR.J+(DT)(ARIR.JK-BDER.J-ARPR.J-0)                        (A996)
12R    ARIR.KL=(SR.JK)(PP)                                            (A997)

       INITIAL CONDITIONS

 6N    AOOR=60                                                        (A998)
 6N    AOIR=OIR                                                       (A999)
 6N    AP1LR=MLF1R                                                    (A1000)
 6N    AP2LR=MLF2R                                                    (A1001)
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PAGE 19    1

    6N    AP3LR=MLP3R                              (A1002)
    6N    ASR=SR                                   (A1003)
    12N   OB=(4)(AOOR)                             (A1004)
    7N    ORD=MIRA-OIR                             (A1005)
    6N    AMU=MIR                                  (A1006)
    12N   MIS=(MLP1R)(MOID)                        (A1007)
    12N   MIP1=(10)(AOOR)                          (A1008)
    12N   MIP2=(9)(AOOR)                           (A1009)
    12N   MIP3=(8)(AOOR)                           (A1010)
    6N    FPAS=AP3LR                               (A1011)
    6N    FLIT=0                                   (A1012)
    6N    TFL=TLR                                  (A1013)
    6N    PLIT=0                                   (A1014)
    12N   TPL=(PFLRD)(TFL)                         (A1015)
    6N    ANPR=NPATR                               (A1016)
    6N    CASH=30000                               (A1017)
    6N    PTD=100000                               (A1018)
    6N    FDL=100000                               (A1019)
    6N    ECL=100000                               (A1020)
    12N   AR=(CPD)(ARIR)                           (A1021)
    12N   AP=(APD)(APIR)                           (A1022)
    19N   P1RFD=(P1MD)(TP11+TP12+TP13+TP14)        (A1023)
    19N   P2RFD=(P2MD)(TP21+TP22+TP23+0)           (A1024)
    18N   P3RFD=(P3MD)(TP31+TP32)                  (A1025)
    12N   RFBDP=(104)(BDR)                         (A1026)
    6N    MLP1G=MP1ER                              (A1027)
    6N    MLP2G=MP2ER                              (A1028)
    6N    MLP3G=MP3ER                              (A1029)
    6N    P1EQL=IP1EL                              (A1030)
    6N    P2EQL=IP2EL                              (A1031)
    6N    P3EQL=IP3EL                              (A1032)
    6N    P1ECQ=P1EQL                              (A1033)
    6N    P2ECQ=P2ECL                              (A1034)
    6N    P3ECQ=P3EQL                              (A1035)
    6N    MNW=NW                                   (A1036)
    6N    ANPAT=NPAT                               (A1037)
    6N    TP1M1=0                                  (A1038)
    6N    TP1M2=0                                  (A1039)
    6N    TP1M3=0                                  (A1040)
    6N    TP1M4=0                                  (A1041)
    6N    TP1M5=0                                  (A1042)
    6N    TD1M1=0                                  (A1043)
    6N    TD1M2=0                                  (A1044)
    6N    TD1M3=0                                  (A1045)
    6N    TD1M4=0                                  (A1046)
    6N    TD1M5=0                                  (A1047)
    6N    TP2M1=0                                  (A1048)
    6N    TP2M2=0                                  (A1049)
    6N    TP2M3=0                                  (A1050)
    6N    TP2M4=0                                  (A1051)
    6N    TP2M5=0                                  (A1052)
    6N    TD2M1=0                                  (A1053)
    6N    TD2M2=0                                  (A1054)
    6N    TD2M3=0                                  (A1055)
    6N    TD2M4=0                                  (A1056)
    6N    TD2M5=0                                  (A1057)
    6N    TP3M1=0                                  (A1058)
    6N    TP3M2=0                                  (A1059)
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PAGE 20 1

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6N    TP3M3=0                                  (A1060)
6N    TP3M4=0                                  (A1061)
6N    TP3M5=0                                  (A1062)
6N    TD3M1=0                                  (A1063)
6N    TD3M2=0                                  (A1064)
6N    TD3M3=0                                  (A1065)
6N    TD3M4=0                                  (A1066)
6N    TD3M5=0                                  (A1067)
6N    TP11=156                                 (A1068)
6N    TP12=52                                  (A1069)
6N    TP13=0                                   (A1070)
6N    TP14=0                                   (A1071)
6N    TP15=0                                   (A1072)
6N    TP21=156                                 (A1073)
6N    TP22=104                                 (A1074)
6N    TP23=52                                  (A1075)
6N    TP31=104                                 (A1076)
6N    TP32=52                                  (A1077)
6N    DT11=TP11                                (A1078)
6N    DT12=TP12                                (A1079)
6N    DT13=TP13                                (A1080)
6N    DT14=TP14                                (A1081)
6N    DT15=TP15                                (A1082)
6N    DT21=TP21                                (A1083)
6N    DT22=TP22                                (A1084)
6N    DT23=TP23                                (A1085)
6N    DT31=TP31                                (A1086)
6N    DT32=TP32                                (A1087)

      POLICY VARIABLES AND CONSTANTS

7A    P1ED.K=P1IED.K+P1AED.K                   (A1088)
7A    P2ED.K=P2IED.K+P2AED.K                   (A1089)
7A    P3ED.K=P3IED.K+P3AED.K                   (A1090)
51A   DCIR.K=CLIP(DFA.K,0,DFI,FAI.K)           (A1091)
51A   MR11S.K=CLIP(0,1,ARI11,P11R.K)           (A1092)
51A   MR12S.K=CLIP(0,1,ARI12,P12R.K)           (A1093)
51A   MR13S.K=CLIP(0,1,ARI13,P13R.K)           (A1094)
51A   MR14S.K=CLIP(0,1,ARI14,P14R.K)           (A1095)
51A   MR15S.K=CLIP(0,1,ARI15,P15R.K)           (A1096)
51A   MR21S.K=CLIP(0,1,ARI21,P21R.K)           (A1097)
51A   MR22S.K=CLIP(0,1,ARI22,P22R.K)           (A1098)
51A   MR23S.K=CLIP(0,1,ARI23,P23R.K)           (A1099)
51A   MR31S.K=CLIP(0,1,ARI31,P31R.K)           (A1100)
51A   MR32S.K=CLIP(0,1,ARI32,P32R.K)           (A1101)
51A   MRS11.K=CLIP(0,1,AR11,P1M1R.K)           (A1102)
51A   MRS12.K=CLIP(0,1,AR12,P1M2R.K)           (A1103)
51A   MRS13.K=CLIP(0,1,AR13,P1M3R.K)           (A1104)
51A   MRS14.K=CLIP(0,1,AR14,P1M4R.K)           (A1105)
51A   MRS15.K=CLIP(0,1,AR15,P1M5R.K)           (A1106)
51A   MRS21.K=CLIP(0,1,AR21,P2M1R.K)           (A1107)
51A   MRS22.K=CLIP(0,1,AR22,P2M2R.K)           (A1108)
51A   MRS23.K=CLIP(0,1,AR23,P2M3R.K)           (A1109)
51A   MRS24.K=CLIP(0,1,AR24,P2M4R.K)           (A1110)
51A   MRS25.K=CLIP(0,1,AR25,P2M5R.K)           (A1111)
51A   MRS31.K=CLIP(0,1,AR31,P3M1R.K)           (A1112)
51A   MRS32.K=CLIP(0,1,AR32,P3M2R.K)           (A1113)
51A   MRS33.K=CLIP(0,1,AR33,P3M3R.K)           (A1114)
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PAGE 21      1

     51A    MRS34.K=CLIP(0,1,AR34,P3M4R.K)                                   (A1115)
     51A    MRS35.K=CLIP(0,1,AR35,P3M5R.K)                                   (A1116)
     C      LTEF=1.05                                                        (A1117)

     PRINT  1)DD,OIR,OB,OOR/2)MPR,MIS,MIR/3)MIP1,MIP2,MIP3/4)MLP1G,MLP2G,MLP3G (A1118)
     X1     /5)FPAS,SR/6)PS,PAD/7)P1EQL,P2EQL,P3EQL/8)FLO,EFL,PLQ,TLR/9)P1L,P2
     X2     L,P3L/10)CASH,PTD,FA1,FDL/11)NW,MNW
     PLOT   P1EQL=1,P2EQL=2,P3EQL=3/FLO=F,PLO=R/CASH=C/PTD=P/NW=N,MNW=M(0,*)   (A1119)
     SPEC   DT=1/LENGTH=104/PRTPER=1/PLTPER=1                                (A1120)

     N      EQUATION FOR MLP1S,  OIR,  MIR,MLP2S,MLP3S, ARIR,ERCSR,  MPR,   SR,   CD
     N      EQUATION FOR   FMD,   DD,  DD5,MLP3R,  P3R,SRIP3,SRII3,RII32, P32R,  R32
     N      EQUATION FOR RII31, P31R,  R31,SRIN3, RI35,P3M5R,RP3M5, RI34,P3M4R,RP3M4
     N      EQUATION FOR  RI33,P3M3R,RP3M3, RI32,P3M2R,RP3M2, RI31,P3M1R,RP3M1,SRCP3
     N      EQUATION FOR SRCI3,SRCN3,MP3GR,MP3ER,P3MER,  DD4,  DD3,MLP2R,  P2R,SRIP2
     N      EQUATION FOR SRII2,RII23, P23R,  R23,RII22, P22R,  R22,RII21, P21R,  R21
     N      EQUATION FOR SRIN2, RI25,P2M5R,RP2M5, RI24,P2M4R,RP2M4, RI23,P2M3R,RP2M3
     N      EQUATION FOR  RI22,P2M2R,RP2M2, RI21,P2M1R,RP2M1,SRCP2,SRCI2,SRCN2,MP2GR
     N      EQUATION FOR MP2ER,P2MER,  DD2,MLP1R,  P1R,SRIP1,SRII1,RII15, P15R,  R15
     N      EQUATION FOR RII14, P14R,  R14,RII13, P13R,  R13,RII12, P12R,  R12,RII11
     N      EQUATION FOR  P11R,  R11,SRIN1, RI15,P1M5R,RP1M5, RI14,P1M4R,RP1M4, RI13
     N      EQUATION FOR P1M3R,RP1M3, RI12,P1M2R,RP1M2, RI11,P1M1R,RP1M1,SRCP1,SRCI1
     N      EQUATION FOR SRCN1,MP1GR,MP1ER,P1MER,  DD1,MMOIR, MIRD, MIRA, MISD,MPRPA
     N      EQUATION FOR   TLR,CP3LA,CP2LA,CP1LA,   NW,   TL,   FL,   CL, APIR,   TA
     N      EQUATION FOR    FA,  BDR, NEBV,P3EBV,P3ECV,P2EBV,P2ECV,P1EBV,P1ECV,   CA
     N      EQUATION FOR  RFBD,   TI,FPASI,MIP3I,  MV3,SPMLF,P3MLF,P2MLF,P1MLF, DMFP
     N      EQUATION FOR P23MF,MIP2I,  MV2,P12MF,MIP1I,  MV1, MISI, NPAT,  TRU,   GP
     N      EQUATION FOR   GPR, BDER, FLCR,  FLQ, PLCR,  PLQ,  MCR, APPR,  OCR, OCRD
     N      EQUATION FOR  P3ED,P3AED,P3M5D,D35FB,DP3M5,D35FA,P3M4D,D34FB,DP3M4,D34FA
     N      EQUATION FOR P3M3D,D33FB,DP3M3,D33FA,P3M2D,D32FB,DP3M2,D32FA,P3M1D,D31FB
     N      EQUATION FOR DP3M1,D31FA,P31ED, P32D, D32E,  D32, P31D, D31E,  D31, P2ED
     N      EQUATION FOR P2AED,P2M5D,D25FB,DP2M5,D25FA,P2M4D,D24FB,DP2M4,D24FA,P2M3D
     N      EQUATION FOR D23FB,DP2M3,D23FA,P2M2D,D22FB,DP2M2,D22FA,P2M1D,D21FB,DP2M1
     N      EQUATION FOR D21FA,P21ED, P23D, D23E,  D23, P22D, D22E,  D22, P21D, D21E
     N      EQUATION FOR   D21, P1ED,P1AED,P1M5D,D15FB,DP1M5,D15FA,P1M4D,D14FB,DP1M4
     N      EQUATION FOR D14FA,P1M3D,D13FB,DP1M3,D13FA,P1M2D,D12FB,DP1M2,D12FA,P1M1D
     N      EQUATION FOR D11FB,DP1M1,D11FA,P11ED, P15D, D15E,  D15, P14D, D14E,  D14
     N      EQUATION FOR  P13D, D13E,  D13, P12D, D12E,  D12, P11D, D11E,  D11, OCRA
     N      EQUATION FOR  P3EE,P3AEE,P3M5E,EP3M5,P3M4E,EP3M4,P3M3E,EP3M3,P3M2E,EP3M2
     N      EQUATION FOR P3M1E,EP3M1,P31EE, P32E,  E32, P31E,  E31, P2EE,P2AEE,P2M5E
     N      EQUATION FOR EP2M5,P2M4E,EP2M4,P2M3E,EP2M3,P2M2E,EP2M2,P2M1E,EP2M1,P21EE
     N      EQUATION FOR  P23E,  E23, P22E,  E22, P21E,  E21, P1EE,P1AEE,P1M5E,EP1M5
     N      EQUATION FOR P1M4E,EP1M4,P1M3E,EP1M3,P1M2E,EP1M2,P1M1E,EP1M1,P11EE, P15E
     N      EQUATION FOR   E15, P14E,  E14, P13E,  E13, P12E,  E12, P11E,  E11, OCRL
     N      EQUATION FOR  GAER,  IER,   IR,  DER,  SIR,   TR,  TRA,  TRB,  AGP, FDLA
     N      EQUATION FOR NPATR
```

APPENDIX B

A GLOSSARY FOR THE HYPOTHETICAL COMPANY GROWTH MODEL

AFWR	average factory wage rate
AGR	additional profits before taxes
AIRFU	average input rate allowing for undercapacity
AMU	average material usage
ANPAT	average net profit after taxes
ANPR	average net profit rate
AOIR	average order input rate
AOOR	average order output rate
AP	accounts payable
APD	accounts payable delay
APIR	accounts payable input rate
APkLR	average process k leaving rate
APPR	accounts payable payment rate
APWR	average professional wage rate
AR	accounts receivable
ARIkn	acceptable reliability level for the nth initial equipment unit in process k
ARIR	accounts receivable input rate
ARkn	acceptable reliability level for the nth acquired equipment unit in process k
ARPR	accounts receivable payment rate

ASR	average shipping rate
ATR	A tax rate
BCV	building cost value
BDER	bad debts expense rate
BDP	bad debt percentage
BDR	building depreciation rate
BTR	B tax rate
CA	current assets
CASH	cash level
CASHA	net cash amount A
CASHB	net cash amount B
CASHT	total cash rate
CD	company demand
CFSkn	cash from salvage of process k machine n
CFSPk	cash from salvage for acquired process k equipment
CHCk	challenger cost for process k
CL	current liabilities
CPD	collection period delay
CPkEA	cash effect of a process k equipment acquisition
CPkL	critical process k labor
CPkLA	critical process k labor required
CRF5	capital recovery factor for five years
CSPkn	cash from salvage of nth initial equipment unit in process k
CSPkT	total cash from salvage of initial equipment units in process k
DCAI	debt capital acquisition indicator

DCIR	debt capital input rate
DD	delivery delay
DD1	order backlog delivery delay
DD2	delivery delay in process one
DD3	delivery delay in process two
DD4	delivery delay in process three
DD5	delivery delay in final storage
DDPPk	double-declining percentage for process k
DER	debt-equity ratio
DFA	debt fund addition
DFI	debt fund increment
DII	debt input indicator
Dkn	depreciation table value for nth initial equipment unit in process k
DknE	actual depreciation expense for nth initial equipment unit in process k
DknFA	depreciation for process k machine n, factor A
DknFB	depreciation for process k machine n, factor B
DMFP	difference between the material and final product price
DPkMn	depreciation for process k machine n
DPPR	debt principal payment rate
DRCkn	decreasing reliability check for process k machine n
DRknC	declining reliability check for the nth initial equipment unit in process k
DTkn	depreciation timing for the nth initial equipment unit in process k

EFL	effective factory labor
Ekn	expense table value for nth initial equipment unit in process k
EOF	effective overhead factor for labor
EPkMn	expense for process k machine n
EPRFI	expected after-tax profit rate for the industry
ERCSR	expected after-tax return from a common share rate
FA	fixed assets
FAI	funds available for investment
FDL	funded debt level
FDLA	after-tax funded debt level adjustment
FHRWU	factory hiring rate with undercapacity
FL	fixed liabilities
FLAT	factory labor averaging time
FLCR	factory labor cost rate
FLD	factory labor desired
FLHR	factory labor hiring rate
FLIT	factory labor in training
FLLR	factory labor leaving rate
FLQ	factory labor quantity
FLRFE	factory labor required for equipment
FLTR	factory labor training rate
FMD	fraction of market demand
FMLPk	final material leaving process k
FPAS	final product awaiting shipment
FPASI	final product awaiting shipment inventory

FTD	factory training delay
FTP	factory turnover percentage
GAEF	general and administrative expense factor
GAER	general and administrative expense rate
GAOF	general and administrative orders factor
GP	profit before taxes
GPR	profit before taxes rate
HRIkn	high reliability time for the nth initial equipment unit for process k
HRTkn	high reliability time for the nth acquired equipment unit
IER	interest expense rate
IMRP2	initial material input rate to process two
IMRP3	initial material input rate to process three
IPkEL	initial process k equipment level
IR	interest rate
IRCO	interest rate cut-off level
LAND	land
LIPk	labor indicator for process k
LLP12	labor left for process one if process two is critical
LLP13	labor left for process one if process three is critical
LLP21	labor left for process two if process one is critical
LLP23	labor left for process two if process three is critical
LLP31	labor left for process three if process one is critical
LLP32	labor left for process three if process two is critical
LP	labor apportionment basis indicator
LPI	labor apportionment index

LPPk	labor provided to process k
LR12	labor remaining for processes one and two
LR13	labor remaining for processes one and three
LR23	labor remaining for processes two and three
LTEF	labor to equipment factor
M12	minimum initial entering rate to processes one and two
M123	minimum initial entering rate to the three processes
MCB	minimum cash balance
MCk	minimum cash for a process k acquisition index
MCPkR	minimum cash required for a process k equipment acquisition
MCR	material cost rate
MD	market demand
MIOR	material input to output ratio
MIPk	material in process k
MIPkI	material in process k inventory
MIR	material input rate
MIRA	material input rate employing policy A
MIRD	material input rate desired
MIS	material in stock
MISD	material in stock desired
MISI	material in stock inventory
MkLS	machine cost for process k less salvage
MLkG	multiple of good material leaving process k
MLPkA	material leaving process k policy A rate
MLPkF	material leaving process k policy F rate
MLPkG	material leaving process k good rate

MLPkR	material leaving process k rate
MLPkS	scrap material leaving process k rate
MMAPk	maximum material allowed in process k quantity
MMLkG	minimum multiple amount of good material leaving process k
MMLPk	minimum machine life for process k
MMOIR	minimum multiple of the order input rate
MNPID	minimum net profit indicator for debt
MNPRD	minimum net profit rate for debt
MNW	market net worth
MOID	number of months of material inventory desired
MOIR	multiple of the order input rate
MPkER	material leaving process k when equipment restricted
MPkLR	material leaving process k when labor restricted rate
MPkGR	total material leaving process k rate
MPP	material purchase price
MPR	material purchase rate
MPRPA	material purchase rate employing policy A
MRknS	minimum reliability signal for process k initial machine n
MRSkn	minimum reliability signal for process k acquied machine n
MUAP	material usage averaging period constant
MVk	market value of process k material
NDP	number of debt payments
NEBV	net equipment book value
NPAT	net profit after taxes
NPATR	net profit after taxes rate
NW	book net worth

OB	order backlog
OCR	overhead cost rate
OCRA	overhead cost rate A
OCRD	overhead cost rate for depreciation
OCRL	overhead cost rate resulting from labor
OFF	overhead fixed cost factor
OIR	order input rate
OOR	order output rate
PAD	process acquisition desired index
PADk	process k acquisition desired indicator level
PAP	purchasing adjustment period constant
PEUFL	percentage effectiveness used for factory labor
PFLRD	professional to factory labor ratio desired
PHRWU	professional hiring rate with undercapacity
PkA	process k acquisition index
PkAED	process k acquired equipment depreciation
PkAEE	process k acquired equipment expense
PkEAQ	process k equipment acquisition quantity
PkEBV	process k equipment book value
PkECQ	process k equipment cost quantity
PkECV	process k equipment cost value
PkED	process k equipment depreciation
PkEE	total process k equipment expense
PkELn	process k initial equipment level plus n
PkEQL	process k equipment quantity level
PkERQ	total process k equipment retirement quantity
PkI	process k acquisition index

PkIEC	process k initial equipment cost
PkIED	process k initial equipment depreciation
PkIEE	process k initial equipment expense
PkIRQ	process k initial equipment replacement quantity
PkL	process k labor
PkLER	process k labor to equipment ratio
PkMD	process k machine depreciation
PkMER	process k material to equipment ratio
PkMLF	process k material to labor factor
PkMLR	process k material to labor ratio
PkMnD	process k machine n actual depreciation
PkMnE	process k machine n actual expense
PkMnR	process k machine n reliability
PkMnS	process k machine n signal
PknD	process k machine n depreciation expense
PknE	equipment expense table value for nth initial equipment unit for process k
PknR	process k initial equipment unit n reliability
PknRQ	process k machine n retirement quantity
PkR	process k reliability
PkRD	process k material rate difference
PkRFD	process k reserve for depreciation
PkRQ	process k retirement quantity
PLAT	professional labor averaging time
PLCR	professional labor cost rate
PLD	professional labor desired

PLDY	professional labor training delay
PLHR	professional labor hiring rate
PLIT	professional labor in training
PLLR	professional labor leaving rate
PLTR	professional labor training rate
P12MF	processes one and two material factor
P23MF	processes two and three material factor
PP	purchase price
PS	process selected
PSI	process selection index
PTD	profit to date
PTP	professional turnover percentage
RFBD	reserve for bad debts
RFBDP	reserve for building depreciation
RIIkn	replacement indicator for initial equipment unit n in process k
RIkn	reliability unit indicator for process k machine n
RIknI	replacement increment for initial equipment unit n in process k
RIknL	replacement indicator for process k machine n level
RILkn	replacement indicator level for initial equipment unit n in process k
Rkn	reliability table value for initial equipment unit n in process k
RknI	retirement indicator for process k machine n
RPkMn	reliability for process k machine n

RQkn	replacement quantity for initial equipment unit n for process k
RR12	relative rate of process one as compared to process two index value
RR13	relative rate of process one as compared to process three index value
RR23	relative rate of process two as compared to process three index value
RSIkn	reliability signal for initial process equipment unit n in process k
RSkn	retirement signal for process k machine n
SD	shipping delay
SIR	sales input rate
Skn	salvage time for initial equipment unit n in process k
SLP12	shared labor for process one if process two is critical
SLP13	shared labor for process one if process three is critical
SLP21	shared labor for process two if process one is critical
SLP23	shared labor for process two if process three is critical
SLP31	shared labor for process three if process one is critical
SLP32	shared labor for process three if process two is critical
SPMLF	sum of the process material to labor factors
SR	shipping rate
SRCNk	sum of reliability values for acquired units in process k
SRINk	reliability unit indicators for process k
SSkn	salvage time for acquired equipment unit n in process k
STkn	salvage time difference for initial equipment unit n in process k

SVkn	salvage value for acquired equipment unit n in process k
SVPkn	salvage value for initial equipment unit n in process k
TA	total assets
TAAPT	time to average the average profit after taxes
TANPR	time to average the net profit rate
TAOIR	time to average the order input rate
TAOOR	time to average the order output rate
TAPkR	time to average the process k leaving rate
TASR	time to average the shipping rate
TCRF5	table of capital recovery factors for a five-year interest period
TDkMn	timing for depreciation for process k machine n
TDkn	timing to stop depreciation for process k machine n
TDPkn	table of depreciation for acquired equipment unit n in process k
TEPkn	table of expense for acquired equipment unit n in process k
TFL	total factory labor
TFMD	table for fraction of market demand
TI	total inventory
TIknJ	timing jump for initial equipment unit n in process k
TIR	table for interest rate
TknJ	timing jump for acquired equipment unit n in process k
TL	total liabilities
TLR	total labor required
TPkMn	timing for acquired equipment unit n in process k
TPkn	timing for initial equipment unit n in process k

TPL	trained professional labor
TPS	table for process selected
TR	tax rate
TRA	tax rate A
TRB	tax rate B
TRU	tax rate used
UA	undercapacity allowed
WCRVk	weekly capital recovery value for process k
YBD	years of building depreciation
YCRVk	yearly capital recovery value for process k
YNPAT	yearly net profit after taxes
YODP	years of debt payment

APPENDIX C

A LISTING OF THE ABC COMPANY GROWTH MODEL PROGRAM

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PAGE 1      1

*      A100-102,DYN,RESULTS,9,9,0,0

       COMPANY GROWTH MODEL - ABC MFG

       SALES INPUT

14A    LS.K=CLA+(CLB)(TIME.K)                                              (B1)
C      CLA=18525.536                                                       (B2)
C      CLB=838.720                                                         (B3)
8A     PS.K=PSP1.K+PSP2.K+PSP3.K                                           (B4)
51A    PSP1.K=CLIP(0,PS1.K,TIME.K,19)                                      (B5)
14A    PS1.K=CP1A+(CP1B)(TIME.K)                                           (B6)
C      CP1A=4147.08                                                        (B7)
C      CP1B=557.436                                                        (B8)
51A    PSP3.K=CLIP(PS3.K,0,TIME.K,31)                                      (B9)
14A    PS3.K=CP3A+(CP3B)(TIME.K)                                           (B10)
C      CP3A=6719.31                                                        (B11)
C      CP3B=62.030                                                         (B12)
7A     PSP2.K=PSP2A.K-PSP2B.K                                              (B13)
51A    PSP2A.K=CLIP(PS2A.K,0,TIME.K,19)                                    (B14)
14A    PS2A.K=CP2A+(CP2B)(TIME.K)                                          (B15)
C      CP2A=29097.05                                                       (B16)
C      CP2B=-730.077                                                       (B17)
51A    PSP2B.K=CLIP(PS2A.K,0,TIME.K,31)                                    (B18)
14A    HS.K=CHA+(CHB)(TIME.K)                                              (B19)
C      CHA=1971.847                                                        (B20)
C      CHB=123.980                                                         (B21)
51A    SS.K=CLIP(SSP1.K,0,TIME.K,47)                                       (B22)
14A    SSP1.K=CSA+(CSB)(TIME.K)                                            (B23)
C      CSA=-7625.92                                                        (B24)
C      CSB=193.044                                                         (B25)
7A     RS.K=RSP1.K+RSP2.K                                                  (B26)
51A    RSP1.K=CLIP(0,RS1.K,TIME.K,34)                                      (B27)
14A    RS1.K=CR1A+(CR1B)(TIME.K)                                           (B28)
C      CR1A=3396.03                                                        (B29)
C      CR1B=-10.139                                                        (B30)
51A    RSP2.K=CLIP(RS2.K,0,TIME.K,34)                                      (B31)
14A    RS2.K=CR2A+(CR2B)(TIME.K)                                           (B32)
C      CR2A=18997.77                                                       (B33)
C      CR2B=-266.440                                                       (B34)
51A    MS.K=CLIP(MSP1,0,TIME.K,32)                                         (B35)
C      MSP1=457                                                            (B36)
10A    TS.K=LS.K+PS.K+HS.K+SS.K+RS.K+MS.K                                  (B37)
10A    TMS.K=LS.K+PS.K+HS.K+SS.K+MS.K+0                                    (B38)
7A     TPS.K=PS.K+SS.K                                                     (B39)

       MACHINE AND LABOR LOADING

12A    WFL.K=(SWFL.K)(LS.K)                                                (B40)
58A    SWFL.K=TABHL(TSWL,TIME.K,1,61,6)                                    (B41)
C      TSWL*=3.03/3.08/2.94/3.62/3.06/3.59/3.46/3.07/3.38/3.14/3.40        (B42)
12A    WFH.K=(SWFH.K)(HS.K)                                                (B43)
58A    SWFH.K=TABHL(TSWH,TIME.K,1,61,6)                                    (B44)
C      TSWH*=2.41/2.64/2.70/2.70/2.47/2.86/2.21/2.50/2.49/2.52/2.47        (B45)
20A    WHBH.K=WHBC.K/HSF                                                   (B46)
C      HSF=0.98                                                            (B47)
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PAGE 2       1

 7A     TWLM.K=WFL.K+WHBH.K                                             (B48)
 20A    TWBL.K=TWLM.K/TSF                                               (B49)
 C      TSF=0.95                                                        (B50)
 12A    WFP.K=(SWFP.K)(PS.K)                                            (B51)
 58A    SWFP.K=TABHL(TSWP,TIME.K,1,61,6)                                (B52)
 C      TSWP*=2.29/2.24/2.21/2.43/2.34/2.20/2.47/2.09/2.56/2.14/1.89    (B53)
 12A    WFS.K=(SWFS)(SS.K)                                              (B54)
 C      SWFS=1.06                                                       (B55)
 12A    CMHR.K=(WHC.K)(TWBL.K)                                          (B56)
 58A    WHC.K=TABHL(TWHC,TIME.K,6,54,12)                                (B57)
 C      TWHC*=0.00521/0.00399/0.00277/0.00224/0.00171                   (B58)
 15A    PMHR.K=(WHP.K)(WFP.K)+(WHS)(WFS.K)                              (B59)
 58A    WHP.K=TABHL(TWHP,TIME.K,6,54,12)                                (B60)
 C      TWHP*=0.00682/0.00609/0.00537/0.00589/0.00650                   (B61)
 C      WHS=0.0108                                                      (B62)
 13A    TMHR.K=(WHT.K)(TWLM.K)(MAF)                                     (B63)
 C      MAF=0.75                                                        (B64)
 58A    WHT.K=TABHL(TWHT,TIME.K,6,54,12)                                (B65)
 C      TWHT*=0.00407/0.00330/0.00253/0.00270/0.00288                   (B66)
 12A    HMHR.K=(WHH.K)(WFH.K)                                           (B67)
 58A    WHH.K=TABHL(TWHH,TIME.K,6,54,12)                                (B68)
 C      TWHH*=0.01042/0.01010/0.00978/0.00999/0.01020                   (B69)
 20A    WHBC.K=WFH.K/CSF                                                (B70)
 C      CSF=0.95                                                        (B71)
 12A    UMHR.K=(WHU.K)(WFH.K)                                           (B72)
 58A    WHU.K=TABHL(TWHU,TIME.K,6,54,12)                                (B73)
 C      TWHU*=0.01065/0.00683/0.00301/0.00709/0.01117                   (B74)
 12A    VMHR.K=(VLF)(CMHR.K)                                            (B75)
 C      VLF=0.20                                                        (B76)
 10A    GLHR.K=CMHR.K+TMHR.K+UMHR.K+HMHR.K+VMHR.K+0                     (B77)
 12A    GLHRA.K=(GLHR.K)(MWFGL)                                         (B78)
 C      MWFGL=1.20                                                      (B79)
 12A    SLHR.K=(GLHRA.K)(GSLPR.K)                                       (B80)
 51A    GSLPR.K=CLIP(GSLPA.K,GSLP.K,TIME.K,42)                          (B81)
 58A    GSLP.K=TABHL(TGSLP,GSLQ.K,10,40,5)                              (B82)
 C      TGSLP*=0.20/0.33/0.40/0.40/0.40/0.40/0.40                       (B83)
 58A    GSLPA.K=TABHL(TGSPA,GSLQ.K,10,40,5)                             (B84)
 C      TGSPA*=0.30/0.43/0.50/0.50/0.50/0.50/0.50                       (B85)
 6A     PLHR.K=PMHR.K                                                   (B86)
 12A    PLHRT.K=(MWFPL)(PLHR.K)                                         (B87)
 C      MWFPL=1.10                                                      (B88)
 7A     GPHRA.K=GLHRA.K+PLHRT.K                                         (B89)
 7A     GSLHR.K=GLHRA.K+SLHR.K                                          (B90)
 12A    CMHA.K=(CQ.K)(CHAPS)                                            (B91)
 C      CHAPS=150                                                       (B92)
 12A    HMHA.K=(HQ.K)(HHAPS)                                            (B93)
 C      HHAPS=170                                                       (B94)
 12A    UMHA.K=(UQ.K)(UHAPS)                                            (B95)
 C      UHAPS=170                                                       (B96)
 12A    TMHA.K=(TQ.K)(THAPS)                                            (B97)
 C      THAPS=160                                                       (B98)
 12A    PMHA.K=(PQ.K)(PHAPS)                                            (B99)
 C      PHAPS=150                                                       (B100)
 12A    VMHA.K=(VQ.K)(VHAPS)                                            (B101)
 C      VHAPS=160                                                       (B102)
 51A    CHP1.K=CLIP(CMHA.K,CMHR.K,CMHR.K,CMHA.K)                        (B103)
 7A     CM23R.K=CMHR.K-CMHA.K                                           (B104)
 51A    C23R.K=CLIP(CM23R.K,0,CM23R.K,0)                                (B105)
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PAGE 3      1

12A   CHA12.K=(2)(CMHA.K)                                    (B106)
51A   CHP2.K=CLIP(CMHA.K,C23R.K,CM23R.K,CMHA.K)              (B107)
7A    CM3R.K=CMHR.K-CHA12.K                                  (B108)
51A   CHP3.K=CLIP(CM3R.K,0,CMHR.K,CHA12.K)                   (B109)
51A   THP1.K=CLIP(TMHA.K,TMHR.K,TMHR.K,TMHA.K)               (B110)
7A    TM23R.K=TMHR.K-TMHA.K                                  (B111)
51A   T23R.K=CLIP(TM23R.K,0,TM23R.K,0)                       (B112)
12A   THA12.K=(2)(TMHA.K)                                    (B113)
51A   THP2.K=CLIP(TMHA.K,T23R.K,TM23R.K,TMHA.K)              (B114)
7A    TM3R.K=TMHR.K-THA12.K                                  (B115)
51A   THP3.K=CLIP(TM3R.K,0,TMHR.K,THA12.K)                   (B116)
51A   UHP1.K=CLIP(UMHA.K,UMHR.K,UMHR.K,UMHA.K)               (B117)
7A    UM23R.K=UMHR.K-UMHA.K                                  (B118)
51A   U23R.K=CLIP(UM23R.K,0,UM23R.K,0)                       (B119)
12A   UHA12.K=(2)(UMHA.K)                                    (B120)
51A   UHP2.K=CLIP(UMHA.K,U23R.K,UM23R.K,UMHA.K)              (B121)
7A    UM3R.K=UMHR.K-UHA12.K                                  (B122)
51A   UHP3.K=CLIP(UM3R.K,0,UMHR.K,UHA12.K)                   (B123)
51A   HHP1.K=CLIP(HMHA.K,HMHR.K,HMHR.K,HMHA.K)               (B124)
7A    HM23R.K=HMHR.K-HMHA.K                                  (B125)
51A   H23R.K=CLIP(HM23R.K,0,HM23R.K,0)                       (B126)
12A   HHA12.K=(2)(HMHA.K)                                    (B127)
51A   HHP2.K=CLIP(HMHA.K,H23R.K,HM23R.K,HMHA.K)              (B128)
7A    HM3R.K=HMHR.K-HHA12.K                                  (B129)
51A   HHP3.K=CLIP(HM3R.K,0,HMHR.K,HHA12.K)                   (B130)
51A   PHP1.K=CLIP(PMHA.K,PMHR.K,PMHR.K,PMHA.K)               (B131)
7A    PM23R.K=PMHR.K-PMHA.K                                  (B132)
51A   P23R.K=CLIP(PM23R.K,0,PM23R.K,0)                       (B133)
12A   PHA12.K=(2)(PMHA.K)                                    (B134)
51A   PHP2.K=CLIP(PMHA.K,P23R.K,PM23R.K,PMHA.K)              (B135)
7A    PM3R.K=PMHR.K-PHA12.K                                  (B136)
51A   PHP3.K=CLIP(PM3R.K,0,PMHR.K,PHA12.K)                   (B137)
51A   VHP1.K=CLIP(VMHA.K,VMHR.K,VMHR.K,VMHA.K)               (B138)
7A    VM23R.K=VMHR.K-VMHA.K                                  (B139)
51A   V23R.K=CLIP(VM23R.K,0,VM23R.K,0)                       (B140)
12A   VHA12.K=(2)(VMHA.K)                                    (B141)
51A   VHP2.K=CLIP(VMHA.K,V23R.K,VM23R.K,VMHA.K)              (B142)
7A    VM3R.K=VMHR.K-VHA12.K                                  (B143)
51A   VHP3.K=CLIP(VM3R.K,0,VMHR.K,VHA12.K)                   (B144)
10A   TGP1.K=CHP1.K+THP1.K+UHP1.K+HHP1.K+VHP1.K+0            (B145)
10A   TGP2.K=CHP2.K+THP2.K+UHP2.K+HHP2.K+VHP2.K+0            (B146)
10A   TGP3.K=CHP3.K+THP3.K+UHP3.K+HHP3.K+VHP3.K+0            (B147)
15A   GSLHA.K=(GSEHA)(GSLG.K)+(PLAGL.K)(1)                   (B148)
C     GSEHA=160                                              (B149)
51A   PLAGL.K=CLIP(PLDA.K,0,PLHA.K,PLHRT.K)                  (B150)
7A    PLDA.K=PLHA.K-PLHRT.K                                  (B151)
15A   GSLEH.K=(GSEHA)(EGSL.K)+(PLAGL.K)(1)                   (B152)
8A    GSLP1.K=GSLHA.K-TGP2.K-TGP3.K                          (B153)
7A    GSOR2.K=GSLHR.K-GSLEH.K                                (B154)
51A   GSOP2.K=CLIP(GSOR2.K,0,GSOR2.K,0)                      (B155)
15A   GSLC1.K=(GSLP1.K)(GSHLR.K)+(EL.K)(GSLMR.K)             (B156)
58A   EL.K=TABHL(TEL,TIME.K,44,60,1)                         (B157)
C     TEL*=0/2/2/6/6/6/7/7/8/8/8/9/9/9/9/9/9                 (B158)
13A   GSC2R.K=(TGP2.K)(SD2A)(GSHLR.K)                        (B159)
C     SD2A=1.05                                              (B160)
20A   GSHLR.K=GSLMR.K/LHPM                                   (B161)
C     LHPM=174                                               (B162)
58A   GSLMR.K=TABHL(TGSMR,TIME.K,1,58,3)                     (B163)
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PAGE 4      1

C     TGSMR*=221/252/255/244/264/286/282/285/303/302/302/306/300/317/303   (B164A)
X1    /295/293/289/275/298                                                  (B164B)
13A   GSC20.K=(GSOP2.K)(1.5)(GSHLR.K)                                       (B165)
7A    GSLC2.K=GSC2R.K+GSC20.K                                               (B166)
13A   GSLC3.K=(TGP3.K)(SD3A)(GSHLR.K)                                       (B167)
C     SD3A=1.07                                                             (B168)
12A   PLHA.K=(PLEHA)(PLG.K)                                                 (B169)
12A   PLEH.K=(PLEHA)(EPL.K)                                                 (B170)
C     PLEHA=160                                                             (B171)
8A    PLP1.K=PLHA.K-PHP2.K-PHP3.K                                           (B172)
7A    POR2.K=PLHRT.K-PLEH.K                                                 (B173)
51A   PLOP2.K=CLIP(POR2.K.0.POR2.K.0)                                       (B174)
12A   PLC1.K=(PLP1.K)(PHLR.K)                                               (B175)
13A   PLC2R.K=(PHP2.K)(SD2A)(PHLR.K)                                        (B176)
20A   PHLR.K=PLMR.K/LHPM                                                    (B177)
58A   PLMR.K=TABHL(TPLMR,TIME.K,1.58,3)                                     (B178)
C     TPLMR*=280/293/293/300/307/364/367/367/367/360/389/389/389/389/389   (B179A)
X1    /389/389/373/349/360                                                  (B179B)
13A   PLC20.K=(PLOP2.K)(1.5)(PHLR.K)                                        (B180)
7A    PLC2.K=PLC2R.K+PLC20.K                                                (B181)
13A   PLC3.K=(PHP3.K)(SD3A)(PHLR.K)                                         (B182)

      COST OF GOODS MANUFACTURED

8A    TCMG.K=TMCMG.K+FWCMG.K+TECMG.K                                        (B183)
10A   TMCMG.K=PCMG.K+ICMG.K+CCMG.K+KCMG.K+BCMG.K+LCMG.K                     (B184)
12A   FWCMG.K=(VACPF)(FWCLV.K)                                              (B185)
10A   FWCLV.K=GSLC1.K+GSLC2.K+GSLC3.K+PLC1.K+PLC2.K+PLC3.K                  (B186)
C     VACPF=1.01238                                                         (B187)
7A    PCMG.K=PCCT+PCVT.K                                                    (B188)
C     PCCT=3699.730                                                         (B189)
16A   PCVT.K=(PCLC)(LS.K)+(PCHC)(HS.K)+(PCPC)(PS.K)+(PCSC)(SS.K)            (B190)
C     PCLC=0.38622                                                          (B191)
C     PCHC=0.70656                                                          (B192)
C     PCPC=0.53194                                                          (B193)
C     PCSC=1.31356                                                          (B194)
7A    ICMG.K=ICCT+ICVT.K                                                    (B195)
C     ICCT=909.823                                                          (B196)
16A   ICVT.K=(ICLC)(LS.K)+(ICHC)(HS.K)+(ICPC)(PS.K)+(ICSC)(SS.K)            (B197)
C     ICLC=0.07696                                                          (B198)
C     ICHC=0.18083                                                          (B199)
C     ICPC=0.09743                                                          (B200)
C     ICSC=-0.09904                                                         (B201)
14A   CCMG.K=CCCT+(CCVC)(LS.K)                                              (B202)
C     CCCT=105.099                                                          (B203)
C     CCVC=0.00255                                                          (B204)
7A    KCMG.K=KCCT+KCVT.K                                                    (B205)
C     KCCT=-41.256                                                          (B206)
16A   KCVT.K=(KCLC)(LS.K)+(KCHC)(HS.K)+(KCPC)(PS.K)+(KCSC)(SS.K)            (B207)
C     KCLC=0.01454                                                          (B208)
C     KCHC=0.03058                                                          (B209)
C     KCPC=0.01242                                                          (B210)
C     KCSC=-0.04379                                                         (B211)
51A   BCMG.K=CLIP(BCMFG.0.TIME.K.47)                                        (B212)
C     BCMFG=200                                                             (B213)
51A   LCMG.K=CLIP(LCMG2.K.0.TIME.K.47)                                      (B214)
14A   LCMG2.K=LCCT+(LCVC)(SS.K)                                             (B215)
C     LCCT=41.157                                                           (B216)
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PAGE 5       1

C      LCVC=0.04599                                              (B217)
7A     TECMG.K=TEMGA.K+TEMGB.K                                   (B218)
11A    TEMGA.K=SCMG.K+PTCMG.K+NCMG.K+GICMG.K+UCMG.K+RCMG.K+MICMG.K+LACMG.  (B219A)
X1     K                                                         (B219B)
8A     TEMGB.K=MRCMG.K+MDCMG.K+WDCMG.K                           (B220)
14A    SCMG.K=SCCT+(SCVC)(TMS.K)                                 (B221)
C      SCCT=94.628                                               (B222)
C      SCVC=0.00414                                              (B223)
14A    PTCMG.K=PTCCT+(PTCVC)(FWCMG.K)                            (B224)
C      PTCCT=71.541                                              (B225)
C      PTCVC=0.03320                                             (B226)
51A    NCMG.K=CLIP(NCMG2.K,0.TIME.K,19)                          (B227)
14A    NCMG2.K=NCCT+(NCVC)(FMBP.K)                               (B228)
C      NCCT=117.427                                              (B229)
C      NCVC=0.00902                                              (B230)
14A    GICMG.K=GICCT+(GICVC)(FMBP.K)                             (B231)
C      GICCT=108.144                                             (B232)
C      GICVC=0.02902                                             (B233)
14A    UCMG.K=UCCT+(UCVC)(TMS.K)                                 (B234)
C      UCCT=342.511                                              (B235)
C      UCVC=0.00545                                              (B236)
14A    RCMG.K=RCCT+(RCVC)(TMS.K)                                 (B237)
C      RCCT=929.530                                              (B238)
C      RCVC=0.00057                                              (B239)
14A    MICMG.K=MICCT+(MICVC)(MEDV.K)                             (B240)
C      MICCT=-25.640                                             (B241)
C      MICVC=0.00154                                             (B242)
14A    LACMG.K=LACCT+(LACVC)(MEDV.K)                             (B243)
C      LACCT=23.032                                              (B244)
C      LACVC=0.00079                                             (B245)
14A    MRCMG.K=MRCCT+(MRCVC)(MEDV.K)                             (B246)
C      MRCCT=-362.873                                            (B247)
C      MRCVC=0.00950                                             (B248)
14A    MDCMG.K=MDCCT+(MDCVC)(MECV.K)                             (B249)
C      MDCCT=253.270                                             (B250)
C      MDCVC=0.00587                                             (B251)
14A    WDCMG.K=WDCCT+(WDCVC)(TMS.K)                              (B252)
C      WDCCT=28.327                                              (B253)
C      WDCVC=0.00024                                             (B254)

       OPERATING COSTS

9A     GP.K=TS.K-IA.K-TCMG.K-FC.K                                (B255)
10A    IA.K=RS.K-IIA-IAC1.K-IAC2.K-IAC3.K-IAC4.K                 (B256)
C      IIA=200                                                   (B257)
51A    IAC1.K=CLIP(IAC1V.0.TIME.K,13)                            (B258)
C      IAC1V=848                                                 (B259)
51A    IAC2.K=CLIP(IAC2V,0,TIME.K,25)                            (B260)
C      IAC2V=-1531                                               (B261)
51A    IAC3.K=CLIP(IAC3V,0,TIME.K,37)                            (B262)
C      IAC3V=852                                                 (B263)
51A    IAC4.K=CLIP(IAC4V.0.TIME.K,49)                            (B264)
C      IAC4V=-1185                                               (B265)
14A    FC.K=FCCT+(FCVC)(TMS.K)                                   (B266)
C      FCCT=-177.315                                             (B267)
C      FCVC=0.06273                                              (B268)
9A     NP.K=GP.K-SAC.K-OE.K+OI.K                                 (B269)
7A     OE.K=IX.K+MDX.K                                           (B270)
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PAGE 6      1

      7A     OI.K=CI.K+MDI.K                                        (B271)
      8A     SAC.K=MBP.K+SACA.K+SACB.K                              (B272)
      11A    SACA.K=CX.K+PT.K+MP.K+MGI.K+TV.K+AC.K+AD.K+NR.K        (B273)
      11A    SACB.K=AI.K+DS.K+LG.K+TT.K+TL.K+OS.K+FD.K+MC.K         (B274)
      51A    CX.K=CLIP(CX2,CXIV.K,TIME.K,33)                        (B275)
      C      CX2=72.8                                               (B276)
      14A    CXIV.K=CXICT+(CXIVC)(TS.K)                             (B277)
      C      CXICT=-487.305                                         (B278)
      C      CXIVC=0.02713                                          (B279)
      14A    PT.K=PTCT+(PTVC)(MBP.K)                                (B280)
      C      PTCT=43.517                                            (B281)
      C      PTVC=0.02151                                           (B282)
      51A    MP.K=CLIP(MPV.K,0,TIME.K,19)                           (B283)
      14A    MPV.K=MPCT+(MPVC)(MBP.K)                               (B284)
      C      MPCT=60.553                                            (B285)
      C      MPVC=0.01496                                           (B286)
      14A    MGI.K=MGICT+(MGIVC)(MBP.K)                             (B287)
      C      MGICT=83.973                                           (B288)
      C      MGIVC=0.01844                                          (B289)
      14A    TV.K=TVCT+(TVVC)(TS.K)                                 (B290)
      C      TVCT=519.463                                           (B291)
      C      TVVC=0.00781                                           (B292)
      14A    AC.K=ACCT+(ACVC)(TS.K)                                 (B293)
      C      ACCT=-90.155                                           (B294)
      C      ACVC=0.00590                                           (B295)
      12A    AD.K=(ADPB)(AUTBV.K)                                   (B296)
      C      ADPB=0.0356                                            (B297)
      51A    NR.K=CLIP(NRV,0,TIME.K,33)                             (B298)
      C      NRV=75                                                 (B299)
      12A    AI.K=(AIPB)(AUTBV.K)                                   (B300)
      C      AIPB=0.00947                                           (B301)
      14A    DS.K=DSCT+(DSVC)(TS.K)                                 (B302)
      C      DSCT=5.725                                             (B303)
      C      DSVC=0.00038                                           (B304)
      14A    LG.K=LGCT+(LGVC)(TS.K)                                 (B305)
      C      LGCT=40.296                                            (B306)
      C      LGVC=0.00348                                           (B307)
      14A    TT.K=TTCT+(TTVC)(TS.K)                                 (B308)
      C      TTCT=260.611                                           (B309)
      C      TTVC=0.00612                                           (B310)
      12A    TL.K=(TLPS)(TS.K)                                      (B311)
      C      TLPS=0.00379                                           (B312)
      14A    OS.K=OSCT+(OSVC)(TMS.K)                                (B313)
      C      OSCT=12.436                                            (B314)
      C      OSVC=0.00483                                           (B315)
      12A    FD.K=(FDPBV)(FFBV.K)                                   (B316)
      C      FDPBV=0.00907                                          (B317)
      51A    MC.K=CLIP(MCV,0,TIME.K,52)                             (B318)
      C      MCV=130                                                (B319)
      14A    IX.K=INCT+(INVC)(MEDV.K)                               (B320)
      C      INCT=-570.550                                          (B321)
      C      INVC=0.01916                                           (B322)
      14A    MDX.K=MDXCT+(MDXVC)(TS.K)                              (B323)
      C      MDXCT=57.009                                           (B324)
      C      MDXVC=0.00013                                          (B325)
      14A    CI.K=CICT+(CIVC)(TMS.K)                                (B326)
      C      CICT=98.128                                            (B327)
      C      CIVC=0.00204                                           (B328)
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PAGE 7 1

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51A   MDI.K=CLIP(MDIV.K.0.TIME.K.18)                                        (B329)
14A   MDIV.K=MDICT+(MDIVC)(TMS.K)                                           (B330)
C     MDICT=94.259                                                          (B331)
C     MDIVC=0.00165                                                         (B332)

      EQUIPMENT STATUS

51R   CAR.KL=CLIP(1.0.CMAR.K.CMARP)                                         (B333)
20A   CMAR.K=CMHR.K/CMHA.K                                                  (B334)
C     CMARP=1.8                                                             (B335)
1L    CQ.K=CQ.J+(DT)(CAR.JK-CRR.JK)                                         (B336)
6R    CRR.KL=0                                                              (B337)
51R   HAR.KL=CLIP(1.0.HMAR.K.HMARP)                                         (B338)
20A   HMAR.K=HMHR.K/HMHA.K                                                  (B339)
C     HMARP=2.0                                                             (B340)
1L    HQ.K=HQ.J+(DT)(HAR.JK-HRR.JK)                                         (B341)
6R    HRR.KL=0                                                              (B342)
51R   UAR.KL=CLIP(1.0,UMAR.K,UMARP)                                         (B343)
20A   UMAR.K=UMHR.K/UMHA.K                                                  (B344)
C     UMARP=2.0                                                             (B345)
1L    UQ.K=UQ.J+(DT)(UAR.JK-URR.JK)                                         (B346)
6R    URR.KL=0                                                              (B347)
51R   TAR.KL=CLIP(1.0.TMAR.K.TMARP)                                         (B348)
20A   TMAR.K=TMHR.K/TMHA.K                                                  (B349)
C     TMARP=3.0                                                             (B350)
1L    TQ.K=TQ.J+(DT)(TAR.JK-TRR.JK)                                         (B351)
6R    TRR.KL=0                                                              (B352)
51R   PAR.KL=CLIP(1.0.PMAR.K.PMARP)                                         (B353)
20A   PMAR.K=PMHR.K/PMHA.K                                                  (B354)
C     PMARP=2.0                                                             (B355)
1L    PQ.K=PQ.J+(DT)(PAR.JK-PRR.JK)                                         (B356)
6R    PRR.KL=0                                                              (B357)
51R   VAR.KL=CLIP(1.0.VMAR.K.VMARP)                                         (B358)
20A   VMAR.K=VMHR.K/VMHA.K                                                  (B359)
C     VMARP=2.0                                                             (B360)
1L    VQ.K=VQ.J+(DT)(VAR.JK-VRR.JK)                                         (B361)
6R    VRR.KL=0                                                              (B362)

      LABOR STATUS

1L    MLIT.K=MLIT.J+(DT)(MLAR.JK-MLTR.JK)                                   (B363)
51R   MLAR.KL=CLIP(1.0.MLQDI.K.MLQ.K)                                       (B364)
7A    MLQ.K=MLIT.K+TML.K                                                    (B365)
14A   MLQDI.K=0.50+(FLQ.K)(FTMLP.K)                                         (B366)
58A   FTMLP.K=TABHL(TFMLP.TIME.K.6.54.12)                                   (B367)
C     TFMLP*=0.446/0.507/0.482/0.429/0.387                                  (B368)
58A   MLMR.K=TABHL(TMLMR.TIME.K.1.58.3)                                     (B369)
C     TMLMR*=582/591/501/545/500/535/512/547/660/660/670/758/743/772/773    (B370A)
X1    /700/655/630/640/629                                                  (B370B)
1L    TML.K=TML.J+(DT)(MLTR.JK-MLLR.JK)                                     (B371)
20R   MLTR.KL=MLIT.K/MLTD                                                   (B372)
C     MLTD=12                                                               (B373)
12R   MLLR.KL=(MTP)(MLQ.K)                                                  (B374)
C     MTP=0.0132                                                            (B375)
13A   MBP.K=(MLQ.K)(MLMR.K)(VACPM)                                          (B376)
C     VACPM=1.04                                                            (B377)
1L    GSLIT.K=GSLIT.J+(DT)(GSLAR.JK-GSLTR.JK)                               (B378)
C     GSOHA=352                                                             (B379)
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PAGE 8 1

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20R   GSLTR.KL=GSLIT.K/GSLTD                                   (B380)
C     GSLTD=5                                                  (B381)
1L    TGSL.K=TGSL.J+(DT)(GSLTR.JK-GSLLR.JK)                    (B382)
15R   GSLLR.KL=(GSTP)(GSLQ.K)+(PLTFG.K)(1)                     (B383)
51A   PLTFG.K=CLIP(1.0.PLAR.JK.1)                              (B384)
7A    GSLQ.K=GSLIT.K+TGSL.K                                    (B385)
C     GSTP=0.102                                               (B386)
14A   EGSL.K=TGSL.K+(EGSIT)(GSLIT.K)                           (B387)
C     EGSIT=0.50                                               (B388)
1L    PLIT.K=PLIT.J+(DT)(PLAR.JK-PLTR.JK)                      (B389)
C     POHA=264                                                 (B390)
20R   PLTR.KL=PLIT.K/PLTD                                      (B391)
C     PLTD=12                                                  (B392)
1L    TPL.K=TPL.J+(DT)(PLTR.JK-PLLR.JK)                        (B393)
12R   PLLR.KL=(PTP)(PLQ.K)                                     (B394)
C     PTP=0                                                    (B395)
14A   EPL.K=TPL.K+(EPLIT)(PLIT.K)                              (B396)
C     EPLIT=0.80                                               (B397)
7A    PLQ.K=PLIT.K+TPL.K                                       (B398)
15A   FMBP.K=(GSLQ.K)(GSLMR.K)+(PLQ.K)(PLMR.K)                 (B399)
8A    FLQ.K=GSLQ.K+PLQ.K+EL.K                                  (B400)

      FIXED ASSETS

1L    MECV.K=MECV.J+(DT)(MEIVG.J+MEIVS.J)                      (B401)
10A   MEIVG.K=ME1I+ME2IC.K+ME3IC.K+ME4IC.K+ME5IC.K+MECSM.K     (B402)
C     ME1I=157                                                 (B403)
51A   ME2IC.K=CLIP(ME2ID.0.TIME.K.13)                          (B404)
C     ME2ID=813                                                (B405)
51A   ME3IC.K=CLIP(ME3ID.0.TIME.K.25)                          (B406)
C     ME3ID=-32                                                (B407)
51A   ME4IC.K=CLIP(ME4ID.0.TIME.K.37)                          (B408)
C     ME4ID=1122                                               (B409)
51A   ME5IC.K=CLIP(ME5ID.0.TIME.K.49)                          (B410)
C     ME5ID=-1314                                              (B411)
51A   SMNI.K=CLIP(1.0.SS.K.1)                                  (B412)
1L    SMIL.K=SMIL.J+(DT)(SMNI.J+0)                             (B413)
49A   SMCI.K=SWITCH(1.0.SMIL.K)                                (B414)
51A   MECSM.K=CLIP(12168.0.SMCI.K.1)                           (B415)
10A   MEIVS.K=NCAC.K+NSPAC.K+NTAC.K+NHAC.K+NVAC.K+NVAC.K       (B416)
51A   NCAC.K=CLIP(NCACV.0.CAR.JK.1)                            (B417)
C     NCACV=42498                                              (B418)
51A   NSPAC.K=CLIP(NSACV.0.PAR.JK.1)                           (B419)
C     NSACV=23700                                              (B420)
51A   NTAC.K=CLIP(NTACV.0.TAR.JK.1)                            (B421)
C     NTACV=6871                                               (B422)
51A   NHAC.K=CLIP(NHACV.0.HAR.JK.1)                            (B423)
C     NHACV=1070                                               (B424)
51A   NUAC.K=CLIP(NUACV.0.UAR.JK.1)                            (B425)
C     NUACV=5439                                               (B426)
51A   NVAC.K=CLIP(NVACV.0.VAR.JK.1)                            (B427)
C     NVACV=8200                                               (B428)
7A    MEDV.K=MECV.K-MEDRL.K                                    (B429)
1L    MEDRL.K=MEDRL.J+(DT)(MDCMG.J+0)                          (B430)
7A    AUTBV.K=ACV.K-ADRL.K                                     (B431)
10A   ACV.K=AIC.K+ACI1.K+ACI2.K+ACI3.K+ACI4.K+ACI5.K           (B432)
51A   AIC.K=CLIP(AICV.0.TIME.K.31)                             (B433)
C     AICV=3237                                                (B434)
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PAGE 9 1

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51A    ACI1.K=CLIP(ACI1V,0,TIME.K,38)                (B435)
C      ACI1V=3646                                     (B436)
51A    ACI2.K=CLIP(ACI2V,0,TIME.K,39)                (B437)
C      ACI2V=1308                                     (B438)
51A    ACI3.K=CLIP(ACI3V,0,TIME.K,44)                (B439)
C      ACI3V=-1308                                    (B440)
51A    ACI4.K=CLIP(ACI4V,0,TIME.K,59)                (B441)
C      ACI4V=3779                                     (B442)
51A    ACI5.K=CLIP(ACI5V,0,TIME.K,60)                (B443)
C      ACI5V=-2924                                    (B444)
1L     ADRL.K=ADRL.J+(DT)(AD.J+0)                     (B445)
7A     FFBV.K=FFCV.K-FFDR.K                           (B446)
14A    FFCV.K=FFICV+(TIME.K)(FFIV)                    (B447)
C      FFICV=3480                                     (B448)
C      FFIV=125                                       (B449)
1L     FFDR.K=FFDR.J+(DT)(FD.J+0)                     (B450)
1L     CNP.K=CNP.J+(DT)(NP.J+0)                       (B451)
1L     FWG.K=FWG.J+(DT)(FWCMG.J+0)                    (B452)
6N     FWG=0                                          (B453)
1L     MBPX.K=MBPX.J+(DT)(MBP.J+0)                    (B454)
6N     MBPX=0                                         (B455)

       INITIAL CONDITIONS

6N     CQ=2                                           (B456)
6N     HQ=1                                           (B457)
6N     UQ=1                                           (B458)
6N     TQ=1                                           (B459)
6N     PQ=1                                           (B460)
6N     VQ=1                                           (B461)
6N     MLIT=0                                         (B462)
6N     TML=3                                          (B463)
6N     GSLIT=2                                        (B464)
6N     TGSL=8                                         (B465)
6N     PLIT=0                                         (B466)
6N     TPL=2                                          (B467)
6N     MECV=61708                                     (B468)
6N     MEDRL=2000                                     (B469)
6N     ADRL=0                                         (B470)
6N     FFDR=80                                        (B471)
6N     SMIL=-1                                        (B472)
1L     CGP.K=CGP.J+(DT)(GP.J+0)                       (B473)
6N     CGP=0                                          (B474)
1L     CSAC.K=CSAC.J+(DT)(SAC.J+0)                    (B475)
6N     CSAC=0                                         (B476)
1L     CTS.K=CTS.J+(DT)(TS.J+0)                       (B477)
6N     CTS=0                                          (B478)
1L     CFC.K=CFC.J+(DT)(FC.J+0)                       (B479)
6N     CFC=0                                          (B480)
1L     CIA.K=CIA.J+(DT)(IA.J+0)                       (B481)
6N     CIA=0                                          (B482)
1L     TG.K=TG.J+(DT)(TCMG.J+0)                       (B483)
6N     TG=0                                           (B484)
1L     TMG.K=TMG.J+(DT)(TMCMG.J+0)                    (B485)
6N     TMG=0                                          (B486)
1L     TEG.K=TEG.J+(DT)(TECMG.J+0)                    (B487)
6N     TEG=0                                          (B488)
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PAGE 10    1

6N     CNP=107                                                              (B489)

       POLICY VARIABLES AND CONSTANTS

51R    GSLAR.KL=CLIP(1.0.GSOP2.K.GSOHA)                                     (B490)
51R    PLAR.KL=CLIP(1.0.PLOP2.K.POHA)                                       (B491)

       OUTPUT SPECIFICATION

PRINT  1)LS,HS,PS,SS,MS,RS,TMS,TS/2)CMHR,TMHR,UMHR,HMHR,VMHR,PMHR/3)CMHA,   (B492A)
X1     TMHA,UMHA,HMHA,VMHA,PMHA/4)CMAR,TMAR,UMAR,HMAR,VMAR,PMAR/5)CMARP,T   (B492B)
X2     MARP,UMARP,HMARP,VMARP,PMARP/6)CQ,TQ,UQ,HQ,VQ,PQ/7)FLQ,MLQ,GSOP2,P   (B492C)
X3     LOP2,FWCMG,MBP,MEDV,AUTBV/8)PCMG,ICMG,CCMG,KCMG,BCMG,LCMG,SCMG,PTC   (B492D)
X4     MG/9)NCMG,GICMG,UCMG,RCMG,MICMG,LACMG,MRCMG,MDCMG/10)WDCMG,FC,IA,C   (B492E)
X5     X,PT,MP,MGI,TV/11)AC,AD,NR,AI,DS,LG,TT,TL/12)OS,FD,MC,IX,MDX,CI,MD   (B492F)
X6     I,NP/13)FWG,MBPX/14)CNP                                              (B492G)
PLOT   CQ=C,TQ=T/GSLHR=R,GSLHA=A/GSOP2=O/CNP=P/FLQ=F,MLQ=M                  (B493)
SPEC   DT=1/LENGTH=60/PRTPER=1/PLTPER=1                                     (B494)

N      EQUATION FOR  PLAR,  VAR,  HAR,  TAR,  PAR,  CAR,  UAR, CMAR, CMHA, CMHR
N      EQUATION FOR  TWBL, TWLM, WHBH, WHBC,  WFH,   HS, SWFH,  WFL,   LS, SWFL
N      EQUATION FOR   WHC, HMAR, HMHA, HMHR,  WHH, UMAR, UMHA, UMHR,  WHU, TMAR
N      EQUATION FOR  TMHA, TMHR,  WHT, PMAR, PMHA, PMHR,  WFS,   SS, SSP1,  WFP
N      EQUATION FOR    PS, PSP3,  PS3, PSP2,PSP2B, PS2A,PSP2A, PSP1, PS1, SWFP
N      EQUATION FOR   WHP, VMAR, VMHA, VMHR,PLOP2, POR2, PLEH,  EPL,PLHRT, PLHR
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APPENDIX D

A GLOSSARY FOR THE ABC COMPANY GROWTH MODEL

AC	advertising cost
ACCT	advertising cost constant term
ACI1	automobile cost increment 1
ACI2	automobile cost increment 2
ACI3	automobile cost increment 3
ACI4	automobile cost increment 4
ACI5	automobile cost increment 5
ACI1V	automobile cost increment 1 value
ACI2V	automobile cost increment 2 value
ACI3V	automobile cost increment 3 value
ACI4V	automobile cost increment 4 value
ACI5V	automobile cost increment 5 value
ACV	automobile cost value
ACVC	advertising cost variable term coefficient
AD	automobile depreciation
ADPB	automobile depreciation percentage of book value
ADRL	automobile depreciation level
AI	automobile insurance
AIC	automobile initial cost
AICV	automobile initial cost value
AIPB	automobile insurance percentage of book value
AUTBV	automobile book value

BCMFG	material B average cost value
BCMG	material B cost
CAR	machine C acquisition rate
CCC	material C constant term
CCMG	material C cost
CCVC	material C variable coefficient
CHA	H sales constant A
CHA12	machine C hours available for the first and second shifts
CHB	H sales coefficient B
CHAPS	machine C hours available per shift
CHP1	machine C hours payable on the first shift
CHP2	machine C hours payable on the second shift
CHP3	machine C hours payable on the third shift
CI	commissions income
CICT	commissions income constant term
CIVC	commissions income variable coefficient
CLA	constant A for L sales
CLB	constant B for L sales
CMAR	machine C acquisition ratio
CMARP	machine C acquisition ratio policy
CMHA	machine C hours available
CMHR	machine C hours required
CM23R	machine C hours remaining for the second and third shifts
CM3R	machine C hours remaining for the third shift
CNP	cumulative net profit
CP1A	P sales period one constant A

CP2A	P sales period two constant A
CP3A	P sales period three constant A
CP1B	P sales period one constant B
CP2B	P sales period two constant B
CP3B	P sales period three constant B
CQ	machine C quantity
C23R	machine C actual hours remaining for the second and third shifts
CR1A	R sales period one constant A
CR2A	R sales period two constant A
CR1B	R sales period one constant B
CR2B	R sales period two constant B
CRR	machine C retirement rate
CSA	S sales constant A
CSB	S sales constant B
CSF	machine C salvage factor
CX	commissions expense
CX2	commissions expense in period two
CX1CT	commission expense constant term in period
CX1V	variable commission expense value in period one
CX1VC	commission expense variable coefficient in period one
DS	dues and subscriptions expense
DSCT	dues and subscription expense constant term
DSVC	dues and subscription expense variable coefficients
EGSIT	effectiveness of general and service labor in training
EGSL	effective general and service labor

EL	excess labor
EPL	effective process labor
EPLIT	effectiveness of process labor in training
FC	freight cost
FCCT	freight cost constant term
FCVC	freight cost variable coefficient
FD	furniture depreciation
FDPBV	furniture depreciation percentage of book value
FFBV	furniture and fixture book value
FFCV	furniture and fixtures cost value
FFDR	furniture and fixtures depreciation reserve
FFICV	furniture and fixtures initial cost value
FFIV	furniture and fixtures increment value
FLQ	factory labor quantity
FMBP	factory monthly base pay
FTMLP	factory to management labor percentage
FWCLV	factory wage cost less vacation pay
FWCMG	factory wage cost
FWG	cumulative factory wage
GICCT	group insurance cost constant term
GICMG	group insurance cost of manufactured goods
GICVC	group insurance cost variable coefficient
GLHR	general labor hours required
CLHRA	general labor hours required actual
GPHRA	general and process hours required actual
GP	gross profit

GSC2O	general and service labor cost for second shift overtime
GSC2R	general and service regular labor cost on the second shift
GSEHA	general and service effective hours available
GSHLR	general and service hourly labor rate
GSHPR	general and service hours policy ratio
GSHPV	general and service hours policy value
GSLAR	general and service labor acquisition rate
GSLC1	general and service labor cost on the first shift
GSLC2	general and service labor cost for the second shift
GSLC3	general and service labor cost for the third shift
GSLEH	general and service labor effective hours
GSLHA	general and service labor hours available
GSLHR	general and service hours required
GSLIT	general and service labor in training
GSLLR	general and service labor leaving rate
GSLMR	general and service labor monthly rate
GSLP	general to service labor percentage
GSLP1	general and service labor hours payable on the first shift
GSLPA	general to service labor percentage A
GSLPR	general to service labor percentage rate
GSLQ	general and service labor quantity
GSLTD	general and service labor training delay
GSLTR	general and service labor training rate
GSOHA	general and service overtime hours allowed
GSOP2	general and service overtime payable on the second shift
GSOR2	general and service overtime required on the second shift

GSTP	general and service labor turnover percentage
HAR	machine H acquisition rate
HHA12	machine H hours available for the first and second shifts
HHAPS	machine H hours available per shift
HHP1	machine H hours payable on the first shift
HHP2	machine H hours payable on the second shift
HHP3	machine H hours payable on the third shift
HMAR	machine H acquisition ratio
HMARP	machine H acquisition ratio policy
HMHA	machine H hours available
HMHR	machine H hours required
HM23R	machine H hours remaining for the second and third shifts
HM3R	machine H hours remaining for the third shift
HQ	machine H quantity
H23R	machine H actual hours remaining for the second and third shifts
HRR	machine H retirement rate
HS	H sales
HSF	machine H salvage factor
IA	inventory adjustment
IAC1	inventory adjustment cost 1
IAC2	inventory adjustment cost 2
IAC3	inventory adjustment cost 3
IAC4	inventory adjustment cost 4
IAC1V	inventory adjustment cost 1 value
IAC2V	inventory adjustment cost 2 value

IAC3V	inventory adjustment cost 3 value
IAC4V	inventory adjustment cost 4 value
ICCT	material I cost constant term
ICHC	material I cost product H coefficient
ICLC	material I cost product L coefficient
ICMG	material I cost of manufactured goods
ICPC	material I cost product P coefficient
ICSC	material I cost product S coefficient
ICVT	material I cost variable term
IIA	initial inventory adjustment
INCT	interest expense constant term
INVC	interest expense variable coefficient
IX	interest expense
KCCT	material K cost constant term
KCHC	material K cost product H coefficient
KCLC	material K cost product L coefficient
KCMG	material K cost of manufactured goods
KCPC	material K cost product P coefficient
KCSC	material K cost product S coefficient
KCVT	material K variable cost term
LACCT	leasehold and amortization cost constant term
LACMG	leasehold ard amortization cost of manufactured goods
LACVC	leasehold and amortization cost variable coefficient
LCCT	material L cost constant term in period two
LCMG	material L cost of manufactured goods
LCMG2	material L cost in period two

LCVC	material L cost variable term in period two
LG	legal and audit expense
LGGT	legal and audit expense constant term
LGVC	legal and audit expense variable coefficient
LHPM	labor hours per month
LS	L sales
MAF	manufactured product adjustment factor
MBP	management base pay
MBPX	cumulative management base pay
MC	miscellaneous and consulting expense
MCV	miscellaneous and consulting expense value
MDCCT	machinery depreciation cost constant term
MDCMG	machinery depreciation cost of manufactured goods
MDCVC	machinery depreciation cost variable coefficient
MDI	miscellaneous and discounts income
MDICT	miscellaneous and discounts income constant term
MDIV	miscellaneous and discounts income value
MDIVC	miscellaneous and discounts income variable coefficient
MDX	miscellaneous and discounts expense
MDXCT	miscellaneous and discounts expense constant term
MDXVC	miscellaneous and discounts expense variable coefficient
MECSM	machinery and equipment cost for a product S unit
MECV	machinery and equipment cost value
MEDRL	machinery and equipment depreciation reserve level
MEDV	machinery and equipment depreciated value
ME1I	initial machinery and equipment increment 1

ME2IC	initial machinery and equipment increment 2
ME3IC	initial machinery and equipment increment 3
ME4IC	initial machinery and equipment increment 4
ME5IC	initial machinery and equipment increment 5
ME2ID	initial machinery and equipment increment 2 value
ME3ID	initial machinery and equipment increment 3 value
ME4ID	initial machinery and equipment increment 4 value
ME5ID	initial machinery and equipment increment 5 value
MEIVG	initial machinery and equipment value
MEIVS	acquired machinery and equipment value
MGI	group insurance expense
MGICT	group insurance expense constant term
MGIVC	group insurance expense variable coefficient
MICCT	machinery and equipment insurance constant term
MICMG	machinery and equipment insurance cost of manufactured goods
MICVC	machinery and equipment insurance variable coefficient
MLAR	management labor acquisition rate
MLIT	management labor in training
MLLR	management labor leaving rate
MLMR	management labor monthly rate
MLQ	management labor quantity
MLQDI	management labor quantity desired indicator
MLTD	management labor training delay
MLTR	management labor training rate
MP	management pension expense
MPCT	management pension expense constant term

MPV	management pension expense value
MPVC	management pension expense variable coefficient
MRCCT	machinery repairs cost constant term
MRCMG	machinery repairs cost of manufactured goods
MRCVC	machinery repairs cost variable coefficient
MS	miscellaneous sales
MSP1	miscellaneous sales value in period one
MTP	management turnover percentage
MWFGL	miscellaneous work factor for general labor
MWFPL	miscellaneous work factor for process labor
NCAC	net cost of an additional machine C
NCACV	net cost value of an additional machine C
NCCT	pension cost constant term
NCMG	pension cost of manufactured goods
NCMG2	pension cost of manufactured goods in period two
NCVC	Pension cost variable coefficient
NHAC	net cost of an additional machine H
NHACV	net cost value of an additional machine H
NP	net profit
NR	location N rent
NRV	location N rent value
NSACV	net cost of acquiring an additional mchine P value
NSPAC	net cost of acquiring an additional machine P
NTAC	net cost of acquiring an additional machine T
NTACV	net cost of acquiring an additional machine T value
NUAC	net cost of acquiring an additional machine U

NUACV	net cost of acquiring an additional machine U value
NVAC	net cost of acquiring an additional machine V
NVACV	net cost of acquiring an additional machine V value
OE	other expense
OI	other income
OS	office supplies expense
OSCT	office supplies expense constant term
OSVC	office supplies expense variable coefficient
PAR	machine P acquisition rate
PCCT	material P cost constant term
PCHC	material P cost product H term
PCLC	material P cost product L term
PCMG	material P cost
PCPC	material P cost product P term
PCSC	material P cost product S term
PCVT	material P variable term
PHA12	machine P hours available for the second and third shifts
PHAPS	machine P hours available per shift
PHLR	process hourly labor rate
PHP1	machine P hours payable on the first shift
PHP2	machine P hours payable on the second shift
PHP3	machine P hours payable on the third shift
PHPR	process hours policy ratio
PHPV	process hours policy value
PLAGL	process labor available for general labor
PLAR	process labor acquisition rate

PLC1	process labor cost for the first shift
PLC2	process labor cost for the second shift
PLC3	process labor cost for the third shift
PLC2O	process labor overtime cost for the second shift
PLC2R	process regular labor cost
PLDA	process labor difference available
PLEH	process labor effective hours
PLEHA	process labor effective hours available
PLHA	process labor hours available
PLHR	process labor hours required
PLHRT	processing labor hours required in total
PLIT	process labor in training
PLLR	process labor leaving rate
PLMR	process labor monthly rate
PLOP2	process labor overtime payable on the second shift
PLP1	process labor hours payable on the first shift
PLQ	process labor quantity
PLTD	process labor training delay
PLTFG	process labor transferred from general
PLTR	process labor training rate
PMAR	machine P acquisition rate
PMARP	machine P acquisition rate policy
PMHA	machine P hours available
PMHR	machine P hours required
PM23R	machine P hours remaining for the second and third shifts
PM3R	machine P hours remaining for the third shift

POHA	process overtime hours
POR2	process labor overtime hours required for the second shift
PQ	machine P quantity
P23R	machine P actual hours remaining for the second and third shifts
PRR	machine P retirement rate
PS	P sales
PS1	P sales during period one
PS3	P sales during period three
PS2A	P sales during period two amount A
PSP1	P sales for period one
PSP2	P sales for period two
PSP3	P sales for period three
PSP2A	P sales for period two amount A
PSP2B	P sales during period two amount B
PT	payroll taxes expense
PTCCT	payroll taxes expense constant term
PTCMG	payroll taxes cost of manufactured goods
PTCT	payroll taxes constant term
PTCVC	payroll taxes expense variable coefficient
PTP	process labor turnover percentage
PTVC	payroll taxes variable coefficient
RCCT	rent cost constant term
RCMG	rent cost of manufactured goods
RCVC	rent cost variable coefficient
RS	purchased product sales

RS1	purchased product sales during period one
RS2	purchased product sales during period two
RSP1	purchased product period one sales
RSP2	purchased product period two sales
SAC	sales and administrative cost
SACA	sales and administrative cost segment A
SACB	sales and administrative cost segment B
SCCT	plant supplies cost constant term
SCMG	plant supplies cost of manufactured goods
SCVC	plant supplies cost variable coefficient
SD2A	shift differential for the second shift
SD3A	shift differential for the third shift
SLHR	service labor hours required
SMCI	machine S acquisition cost indicator
SMIL	machine S initial level
SMNI	machine S addition indicator
SS	S sales
SSP1	S sales during period one
SWFH	sales to weight factor for product H
SWFL	sales to weight factor for product L
SWFP	sales to weight factor for product P
SWFS	sales to weight factor for product S
TAR	machine T acquisition rate
TCMG	total cost of manufactured goods
TECMG	total expense cost of manufactured goods
TEL	table of values for excess labor

TEMGA	total expense cost of manufactured goods segment A
TEMGB	total expense cost of manufactured goods segment B
TFMLP	table of values for factory to management labor percentage
TGP1	total general labor hours payable on the first shift
TGP2	total general labor hours payable on the second shift
TGP3	total general labor hours payable on the third shift
TGSL	trained general and service labor
TGSLP	table of values for the general to service labor percentage
TGSMR	table of values for the general to service labor monthly rate
TGSPA	table of general to service percentage A
THA12	machine T hours available for first and second shifts
THAPS	machine T hours available per shift
THP1	machine T hours payable on first shift
THP2	machine T hours payable on second shift
THP3	machine T hours payable on third shift
TL	taxes and licenses expense
TLPS	taxes and licenses expense percentage of sales
TMAR	machine T acquisition ratio
TMARP	machine T acquisition ratio policy
TMCMG	total material cost of manufactured goods
TMHA	machine T hours available
TMHR	machine T hours required
TML	trained management labor
TMLMR	table of values for management labor monthly rate
TM23R	machine T hours remaining for the second and third shifts
TM3R	machine T hours remaining for the third shift

TMS	total manufactured sales
TPL	trained process labor
TPLMR	table of the process labor monthly rate
TPS	total P sales
TQ	machine T quantity
T23R	machine T actual hours remaining for the second and third shifts
TRR	machine T retirement rate
TS	total sales
TSF	machine T salvage factor
TSWH	table of sales to weight factors for product H
TSWL	table of values to the sales to weight factors for product L
TSWP	table of sales to weight factors for product P
TT	telephone and telegraph expense
TTCT	telephone and telegraph expense constant term
TTVC	telephone and telegraph expense variable coefficient
TV	travel expense
TVCT	travel expense constant term
TVVC	travel expense variable coefficient
TWBL	total weight of beginning product L material
TWHC	table of values for weight to hours factors for machine C
TWHH	table of weight to hours factors for machine H
TWHP	table of weight to hours factors for machine P
TWHT	table of weight to hours factors for machine T
TWHU	table of weight to hours factors for machine U
TWLM	total weight of product L manufactured

UAR	machine U acquisition rate
UCCT	utilities cost constant term
UCMG	utilities cost of manufactured goods
UCVC	utilities cost of variable coefficient
UHA12	machine U hours available for the first and second shifts
UHAPS	machine U hours available per shift
UHP1	machine U hours payable on first shift
UHP2	machine U hours payable on second shift
UHP3	machine U hours payable on third shift
UMAR	machine U acquisition ratio
UMARP	machine U acquisition ratio policy
UMHA	machine U hours available
UMHR	machine U hours required
UM23R	machine U hours remaining for the second and third shifts
UM3R	machine U hours remaining for the third shift
UQ	machine U quantity
U23R	machine U actual hours remaining for the second and third shifts
URR	machine U retirement rate
VACPF	vacation cost percentage for factory labor
VACPM	vacation cost percentage for management labor
VAR	machine V acquisition rate
VHA12	machine V hours available for the first and second shifts
PHAPS	machine V hours available per shift
VHP1	machine V hours payable on the first shift
VHP2	machine V hours payable on the second shift

VHP3	machine V hours payable on the third shift
VLF	machine V usage factor
VMAR	machine V acquisition ratio
VMARP	machine V acquisition ratio policy
VMHA	machine V hours available
VMHR	machine V hours required
VM23R	machine V hours remaining for the second and third shifts
VM3R	machine V hours remaining for the third shift
VQ	machine V quantity
V23R	machine V actual hours remaining for the second and third shifts
VRR	machine V retirement rate
WDCCT	waste disposal cost constant term
WDCMG	waste disposal cost of manufactured goods
WDCVC	waste disposal cost variable coefficient
WFH	weight of final product H
WFL	weight of final product L
WFP	weight of final product P
WFS	weight of final product S
WHBC	weight of product H before machine C
WHBH	weight of product H before machine H
WHC	weight to hours factor for machine C
WHH	weight to hours factor for machine H
WHP	weight to hours factor for machine P
WHS	weight to hours factor for machine S
WHT	weight to hours factor for machine T
WHU	weight to hours factor for machine U

APPENDIX E

DATA OBTAINED FROM THE ABC COMPANY

Because of the proprietary nature of information provided by the ABC Company, it was requested by the company president and considered appropriate that this information be retained by Dr. Joseph Krol, Chairman of the Thesis Committee, under separate cover.

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VITA

Philip E. Hicks was born in Malden, Massachusetts, on March 16, 1933. He attended public schools in Wakefield, Massachusetts, where he was graduated from Wakefield High School in June, 1950.

The author entered Northeastern University, Boston, Massachusetts, in September, 1950, to pursue an industrial engineering education. In February, 1952, following his family's move to Florida, he transferred to the University of Miami, Coral Gables, Florida.

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In the period from August, 1958, to September, 1963, Mr. Hicks was employed successively as follows: six months with the General Electric Company, Schenectady, New York, in its Manufacturing Training Program; two and one-half years with the Sperry Electronic Tube Division, Gainesville, Florida, as an industrial engineer; one semester with the Industrial Engineering Department, University of Florida, as an interim instructor; and one and one-half years with the Electro-Mechanical Research Corporation, Sarasota, Florida, as a Manufacturing Engineering Section head.

In September, 1963, the author entered the Georgia Institute of

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